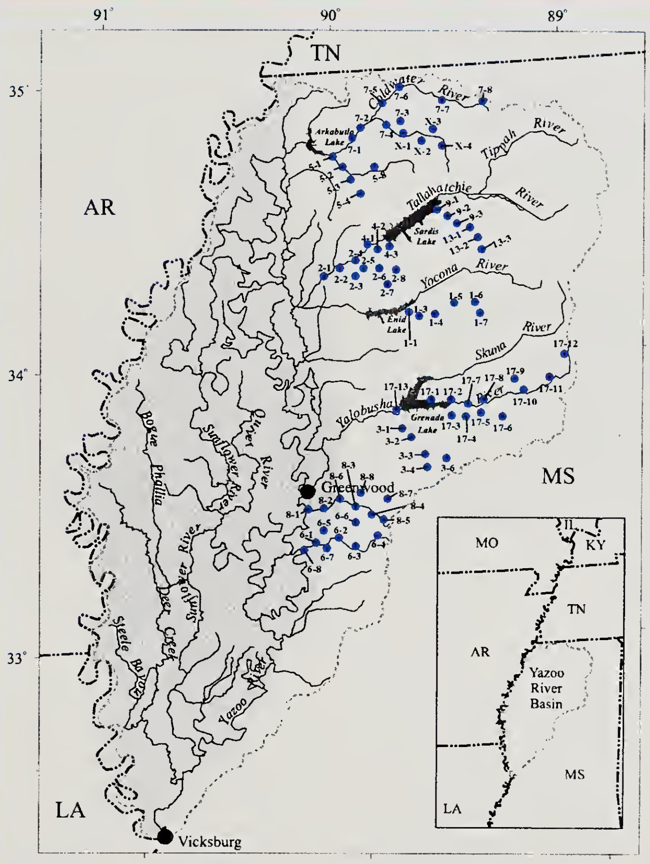
Agricultural Research Service

Water Quality & Ecological Processes Research Unit
National Sedimentation Laboratory
Oxford, Mississippi 38655

Water Quality in Northern Mississippi Hill Land Streams in the Demonstration Erosion Control (DEC) Project: Calendar Year 2000



Richard E. Lizotte, Jr., Charles M. Cooper, James T. Hill, Marjorie M. Holland, Matthew T. Moore, and Scott S. Knight

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Calendar Year 2000

EXECUTIVE SUMMARY

Statement of Purpose

As part of the Demonstration Erosion Control (DEC) Project in the Yazoo Basin, the Water Quality and Ecological Processes Research Unit at the USDA-ARS National Sedimentation Laboratory was requested by the US Army Corps of Engineers, Vicksburg District, to document current water quality. The DEC project in the Yazoo Basin is a cooperative interagency project, including the Corps of Engineers, the Natural Resources Conservation Service and the Agricultural Research Service, aimed at flood control and reducing erosion and channel instability. Additional goals of DEC include demonstration of innovative management techniques, total watershed planning, water quality, improved ecosystem health and environmental enhancement. Currently, consistent characterization of water quality is performed in eleven hill land stream watersheds as part of a larger database including habitat, animal and plant diversity to assess ecosystem health. Results are used to provide a constant evaluation of DEC water quality conditions and long term changes. This information is also useful in developing realistic total maximum daily loads (TMDLs) within the Yazoo Basin.

Evaluation

Samples from each watershed were routinely collected biweekly or monthly. Physical, chemical and biological water parameters measured were pH, temperature, dissolved oxygen, conductivity, salinity, turbidity, alkalinity, hardness, depth to water, depth of water, total, suspended and dissolved solids, filtered orthophosphate, total orthophosphate, ammonia, nitrate, total kjeldahl nitrogen, chlorophyll *a*, fecal coliforms and enterococci. Analyses were performed according to standard water quality methods (APHA, 1992).

Results

Fluctuations in temperature, dissolved oxygen, and conductivity were often associated with seasonal changes and low-flow drought conditions. Changes in pH were mostly associated with storm events and fluctuations in chlorophyll *a* concentrations. Solids, specifically suspended solids concentrations, exhibited fluctuations most frequently occurring with significant storm events (1" or more of rainfall). Fluctuations in nutrient concentrations were commonly associated with application processes and ensuing nutrient runoff after rainfall events. Observed peaks in microbial counts during calendar year 2000 were due primarily to low flows during drought conditions occurring in summer and fall.

Most water quality parameters were consistently within acceptable limits of USEPA and MDEQ TMDL guidelines during calendar year 2000. Non-compliant values with a frequency of occurrence of 25% or greater during calendar year 2000 were observed for pH, total orthophosphate, chlorophyll *a*, and summer fecal coliforms (between May and October) in all eleven watersheds studied in the Yazoo basin.

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NOTE

*All report tables and figures are labeled according to the DEC watershed number (e.g. "2" for Long watershed, "4" for Hotophia watershed, etc.) except Figure 1, Figures 18-1 through 18-4, and Figures 19-1 through 19-3. The report was formatted as such to facilitate access to certain information for specific watersheds. Because of this, there are no tables and figures with the numbers 10, 11, 12, 14, 15, or 16. The following is a complete list of watershed names and associated DEC numbers.

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ACKNOWLEDGMENTS

The authors wish to thank Leslie Arbuckle, Corrie Langley Beard, Miguel Villegas, Jason Greer, Ashley McBride, Charles Bryant, Timothy Beard, Sam Testa, and Terry Welch, for technical assistance. Appreciation is also extended to Paul Rodrigue, Sammie Smith, and Doug Shields for reviewing an earlier version of this report. This research was funded in part by the United States Army Corps of Engineers, Vicksburg District. Construction of watershed bank stabilization and erosion control structures was conducted by the U.S. Army Corps of Engineers and the USDA Natural Resources Conservation Service.

INTRODUCTION

Degradation of stream surface water quality has been highlighted as a pervasive and persistent problem throughout the United States, but especially in areas with highly erodible soils, such as those found in northern Mississippi. Water quality degradation can be attributed to many factors, with erosion having a major role. Other contributing factors include, but are not limited to, pesticides, nutrients, and animal and municipal waste. This research addresses the issue of water quality in north Mississippi streams of the Yazoo Basin which have been designated through the Demonstration Erosion Control (DEC) Project as impacted by at least one of the above mentioned contributing factors.

As part of the DEC Project in the Yazoo Basin, the Water Quality and Ecological Processes Research Unit at the USDA-ARS National Sedimentation Laboratory was requested by the US Army Corps of Engineers, Vicksburg District, to characterize current water quality. The DEC project in the Yazoo Basin is a cooperative interagency project, including the Corps of Engineers, the Natural Resources Conservation Service and the Agricultural Research Service, aimed at flood control and reducing erosion and channel instability. Additional goals of DEC include demonstration of innovative management techniques, total watershed planning, water quality improvement, ecosystem health improvement, and environmental enhancement.

Currently, consistent characterization of water quality is performed in designated watersheds as part of a larger database including habitat, animal and plant diversity. This information has proven valuable in assessing ecosystem health, specific problems in DEC watersheds, and in evaluating long-term changes resulting from DEC stabilization and rehabilitation efforts. Such information is also useful in developing realistic total maximum daily loads (TMDLs) within the Yazoo Basin. Individual TMDLs are based upon the total daily amount of a material (such as total solids or nutrients) in a body of water from natural, point and non-point sources that would not have a deleterious effect on aquatic life. TMDLs also include a margin of safety measurement to help account for uncertainty.

Sediment has been reported as the single most abundant pollutant (by volume) in the Nation's rivers and streams (Fowler and Heady, 1981). For example, the 1996 National Water Quality Inventory stated that about 40% of the nation's surveyed rivers, lakes, and estuaries had water quality impairment, and suspended sediment was the most widespread pollutant impacting surveyed rivers and streams (USEPA, 1997). Sediment-related problems are the most severe in certain regions developed for agriculture. Highly erodible soils, a humid climate, and a history of channelization and watershed mismanagement in north Mississippi have produced severe erosion and sedimentation problems. Sediment yield from the northern Mississippi hill land streams is about twice the national average, or about 3000 tons per square mile per year. Most streams in this region have experienced accelerated erosion within the last 30 years, often increasing their channel size three to tenfold. Statistics are not available for northern Mississippi alone, but on a statewide basis, 95% of all stream miles do not fully support aquatic life uses, and 91% do not fully support swimming (MDEQ, 1999).

These severe conditions produce a situation ideal for research and development of technology for widespread application. Because water is the basis for life, this issue is in critical need of attention. Maintaining water quality assures agriculture a water supply for crops and livestock. Likewise, it provides a potable supply of drinking water for municipalities, communities, and individuals. Hence, life itself hinges on water quality.

MATERIALS AND METHODS

Samples from each watershed were collected and preserved (using ice) twice each month, with the exception of the Toby Tubby, Burney Branch, Abiaca, Black, and Batupan Bogue watersheds, which were collected monthly. General site observations were made and noted at each sample collection. Water chemistry measurements of pH, temperature, dissolved oxygen, conductivity, and salinity using calibrated electronic meters was measured. Depth of the water column was also collected at each site as well as depth to water (recorded from the top of the collection site [bridge rail] to the top of the water's surface).

Preserved samples were transported to the USDA-ARS National Sedimentation Laboratory, Oxford, Mississippi. Physical and chemical parameters consisting of total solids, dissolved solids, suspended solids, ammonia, nitrates, filtered orthophosphate, total orthophosphate, chlorophyll *a*, fecal coliforms, and enterococci were analyzed using standard methods (APHA, 1992). Several additional parameters were initiated during calendar year 2000. These included total kjeldahl nitrogen beginning in June 2000; turbidity beginning in August 2000; alkalinity, hardness and salinity beginning in December 2000.

RESULTS

Otoucalofa

Most basic water quality parameters (temperature, conductivity, salinity, dissolved oxygen, and turbidity) for Otoucalofa sampling sites (Fig. 1) remained consistent according to typical seasonal fluctuations. Measurements of pH showed some fluctuations but were related in part to fluctuations in total chlorophyll *a* concentrations and storm events. Depth to water and water depth remained constant throughout most of the year, fluctuating minimally with periods of drought and rain. Solids (total, dissolved, suspended) remained fairly constant, with most noticeable deviation occurring on 4/03/00, which was associated with a significant rainfall event (approximately 2"). Likewise, orthophosphate concentrations remained generally constant over the year, with the occasional peak, most likely due to nutrient runoff from fertilizer application. Nitrate, ammonia and total kjeldahl concentrations followed similar patterns with peaks often associated with animal remains at or near the sampling locality. Site 1,1 (see Fig. 1) consistently had greater nutrient concentrations (Fig. 1-3, Fig. 1-4) associated with an upstream wastewater treatment facility for the city of Water Valley. Fecal coliform peaks occurred on 7/10/00 and 9/05/00 during low-flow conditions. Site 1,6 had consistently greater enterococci measurements than other sampling sites during calendar year 2000. According to USEPA and Mississippi

Department of Environmental Quality (MDEQ) water quality (TMDL) guidelines (USEPA, 1986; MDEQ, 1999), 14 of 18 water quality parameters for Otoucalofa Creek were frequently (>75% of observations) within acceptable limits. Exceptions were limited to pH, total orthophosphate, chlorophyll *a*, and summer fecal coliforms (from May to October 2000). Site 1,1 (downstream of the Water Valley wastewater treatment facility) accounted for most of the non-compliant orthophosphate concentrations. For complete data see Figures 1-1 to 1-5, 18-1, and 19-1 to 19-3.

Long

As with Otoucalofa, basic water quality parameters (temperature, conductivity, salinity, dissolved oxygen, pH, turbidity, alkalinity and hardness) were consistent with seasonal fluctuations among sites (Fig. 1). Likewise, depth to water and water depth remained fairly constant with an occasional significant change due to rainfall events. Solids concentrations (total, dissolved, suspended) were relatively constant with the exception of a distinguishing peak on 4/03/00 associated with a storm event which produced two inches of rainfall. Filtered orthophosphate, total orthophosphate, ammonia, nitrate and total kjeldahl concentrations exhibited peaks of various magnitudes, most often associated with storm events, nutrient runoff, or animal remains. Fecal coliforms had a significant increase in colonies during the warmer months for all sites, while enterococci exhibited peaks during late spring and early summer. Similarly to Otoucalofa, most water quality parameters were predominantly within acceptable limits of USEPA and MDEQ TMDL guidelines. Non-compliance frequently occurred (>25% of observations) for pH, total orthophosphate, chlorophyll *a* and summer fecal coliforms (from May to October 2000). Complete data are shown in Figures 2-1 through 2-6, 18-1 and 19-1 through 19-3.

Batupan Bogue

Temperature, conductivity, salinity, dissolved oxygen, and turbidity remained relatively consistent (with seasonal fluctuations) among sites (Fig. 1) throughout the year. Measurements of pH showed some fluctuations associated in part to fluctuations in total chlorophyll *a* concentrations and storm events. Depth to water and water depth responded primarily to storm events. Solids concentrations (total, dissolved, and suspended) showed significant peaks for total and suspended solids occurring on 3/27/00 and 6/19/00, most likely associated with 1"+ rainfall events. Filtered and total orthophosphate concentrations, as well as ammonia, nitrate and total kjeldahl concentrations exhibited a peak on 6/19/00 (due to a storm event), with smaller fluctuations throughout the year. Bacterial contamination also exhibited peaks on 6/19/00, again due to a storm event. The majority of water quality measurements were within acceptable limits of USEPA and MDEQ guidelines although exceptions frequently occurred (>25% of observations) for pH, total orthophosphate, chlorophyll *a* and summer fecal coliforms during 2000. Complete data is presented in Figures 3-1 to 3-5, 18-1, and 19-1 to 19-3.

Hotophia

Sampling locations for Hotophia Creek are presented in Figure 1. As with prior watersheds, temperature, conductivity, salinity, dissolved oxygen, turbidity, hardness, alkalinity and pH displayed seasonal fluctuations. Depth to water and water depth remained relatively constant, with the exception of peaks on 4/24/00 and 6/19/00 that were associated with significant (2" or more) rainfall events. These storm events produced the peaks in solids and nutrients concentrations on 4/24/00 and 6/19/00. Both fecal coliforms and enterococci showed significant increases during the spring and summer months. Most water quality parameters for Hotophia Creek were within acceptable limits of USEPA and MDEQ TMDL guidelines. Non-compliance frequently occurred for pH, total orthophosphate, chlorophyll *a*, and summer fecal coliforms. Complete information is presented in Figures 4-1 to 4-6, 18-2, and 19-1 to 19-3.

Hickahala

Locations for each sampling station along Hickahala Creek are shown in Figure 1. Temperature, dissolved oxygen, conductivity, salinity, turbidity, and pH generally followed seasonal fluctuations. Depth to water and water depth remained relatively constant for most of the sites except site 5,1, which had significant fluctuation in depth throughout the year due to influences from Arkabutla Lake. Total and suspended solid concentrations had a marked peak on 4/03/00 that coincided with a one-inch rainfall event. Nutrient concentrations exhibited sporadic peaks primarily during the spring and early summer months and were probably associated with storm events, nutrient runoff and application processes at or near the sampling locality. Increases in fecal coliforms occurred during early spring, late summer and fall. Peaks in enterococci were present during fall and winter months. Again, the majority of water quality measurements were within acceptable limits of USEPA and MDEQ TMDL guidelines, although non-compliance frequently occurred for pH, total orthophosphate, chlorophyll *a*, and summer fecal coliforms during calendar year 2000. See Figures 5-1 to 5-5, 18-2 and 19-1 to 19-3 for complete information.

Black

Sampling stations for Black Creek are presented in Figure 1. Depth to water and water depth remained relatively constant throughout the year with a peak occurring during a storm event on 4/03/00. Temperature, conductivity, salinity, turbidity, dissolved oxygen concentrations and pH, were consistent with seasonal fluctuations throughout the year. Solids concentrations exhibited a significant peak during a storm event on 4/03/00. Nutrient analyses exhibited fluctuations throughout the year with peaks associated with storm events, nutrient runoff and application processes at or near the sampling locality. Microbial analyses showed increases in fecal coliforms for most sites during the summer and fall months with most sites having sporadic peaks throughout the year. Thirteen of 16 water quality parameters were frequently (>75% of observations) within acceptable limits of USEPA and MDEQ guidelines. Non-compliance frequently

occurred primarily for total orthophosphate, chlorophyll *a*, and summer fecal coliforms. For complete data refer to Figures 6-1 to 6-5, 18-2, and 19-1 to 19-3.

Coldwater/Pigeon Roost

Sampling locations for Coldwater River and Pigeon Roost Creek are presented in Figure 1. Depth-to-water was relatively constant with notable fluctuations occurring on 3/20/00 and 4/03/00, which coincided with storm events (1 - 2"). Basic water quality parameters (temperature, salinity, dissolved oxygen, turbidity, and pH) were consistent with seasonal fluctuations. Conductivity exhibited a marginal increase, primarily in the summer months, at sites 7,3 and X,4. Total and suspended solids concentrations exhibited significant peaks on 4/03/00 and were associated with a rainfall event (1 - 1.5"). Site X,2 had two other peaks on 5/30/00 and 10/16/00 that coincided with recent land development in the area. Filtered and total orthophosphate, ammonia, nitrate, and total kjeldahl nitrogen concentrations exhibited fluctuations throughout the year with peaks associated with development, storm events, nutrient runoff and application processes at or near the sampling locality. Both fecal coliforms and enterococci had significant increases during the summer months and are most likely associated with animal remains and/or low-flow conditions. Similar to other watersheds examined, Coldwater/Pigeon Roost had 12 of 16 water quality measurements that were often (>75%) within acceptable limits of USEPA and MDEQ TMDL guidelines. Suspended solids, pH, chlorophyll *a*, and summer fecal coliforms commonly (>25%) exceeded the guidelines during 2000. See Figures 7-1 to 7-5, 18-3, and 19-1-19-3 for complete data.

Abiaca

Locations of sampling sites for Abiaca Creek are shown in Figure 1. Water depth and depth to water remained relatively constant throughout the year except for a peak occurring on 4/03/00 coinciding with a 1-2" rainfall event. Temperature, dissolved oxygen, salinity, turbidity, and pH generally followed seasonal fluctuations among sites throughout calendar year 2000. Conductivity showed a significant decrease coinciding with the storm event on 4/03/00. Total and suspended solids concentrations had significant peaks occurring on 4/03/00, 6/26/00, 09/18/00 and 11/13/00 in conjunction with significant rainfall events (1-2"). Filtered and total orthophosphate fluctuated throughout the year with peaks occurring on 4/03/00, 6/26/00, 9/18/00 and 11/13/00 often coinciding with rainfall events. Nitrates, ammonia and total kjeldahl had significant increases during the winter months. Microbial analyses indicated consistent numbers of fecal coliforms and enterococci throughout much of 2000 with peaks occurring throughout the summer and associated with low-flow conditions. Similar to other DEC watersheds, 12 of 16 water quality parameters were often (>75% of observations) within acceptable limits of USEPA and MDEQ guidelines. Non-compliance often (>25% of observations) occurred for pH, total orthophosphate, chlorophyll *a*, and summer fecal coliforms. Refer to Figures 8-1 to 8-5, 18-3, and 19-1 to 19-3 for complete information.

Toby Tubby

Water depth and depth to water remained relatively constant throughout the year. Temperature, dissolved oxygen, conductivity, salinity, hardness, alkalinity, turbidity, and pH followed seasonal fluctuations throughout calendar year 2000. Total and suspended solids concentrations fluctuated throughout calendar year 2000 with significant peaks primarily coinciding with a rainfall event. Nutrients fluctuated throughout calendar year 2000 with increases in concentrations occurring primarily with nutrient runoff from application processes or precipitation events at or near the sampling locality. Fecal coliform and enterococci measurements exhibited an unexplained significant peak at site 9,4 on 6/05/00. Most water quality parameters for Toby Tubby Creek were within acceptable limits of USEPA and MDEQ TMDL guidelines. Exceptions occurred for total orthophosphate, chlorophyll *a*, and fecal coliforms. See Figure 1 for locations of Toby Tubby Creek sampling sites. More specific data are available in Figures 9-1 to 9-6, 18-3, and 19-1 to 19-3.

Burney Branch

Several water quality parameters (temperature, conductivity, salinity, turbidity, hardness, alkalinity, and dissolved oxygen) measured at sampling sites for Burney Branch Creek remained consistent according to typical seasonal fluctuations and storm events. Measurements of pH showed some fluctuations and a general increase throughout the year but were due in part to fluctuations in chlorophyll *a* concentrations and storm events. Water depth and depth to water remained constant throughout the year. Total, dissolved and suspended solids fluctuated throughout the year with site 13-3 having consistently greater concentrations. Observed fluctuations in solids concentrations are associated primarily with storm events and recent land development in the area. Filtered and total orthophosphate remained relatively stable throughout calendar year 2000 for sites 13,1 and 13,2 while site 13,3 fluctuated. Again, site 13,3 had significantly higher phosphorus concentrations than other sites throughout 2000 due to recent land development near that site. Ammonia and total kjeldahl nitrogen concentrations exhibited occasional peaks during the summer and fall. Nitrate concentrations fluctuated throughout the year at site 13,3, with significantly greater amounts recorded during the summer and fall months. Microbial analyses revealed fluctuations in fecal coliform and enterococci numbers with peaks generally observed during spring and summer months. Fifteen of 18 water quality parameters for Burney Branch Creek were frequently (>75% of observations) within acceptable limits of USEPA and MDEQ guidelines. Non-compliance often (>25% of observations) occurred for total orthophosphate, chlorophyll *a*, and summer fecal coliforms. See Figures 13-1 to 13-6, 18-4, 19-1 to 19-3 for more specific information.

Yalobusha

Water depth and depth to water remained relatively constant throughout the year, except at site 17,1 (Grenada Lake) where water levels dropped throughout the summer and fall due to drought conditions and lake-management draw-down. Temperature,

dissolved oxygen, salinity, turbidity, hardness, and alkalinity remained relatively similar within expected seasonal fluctuations throughout calendar year 2000. Conductivity increased during the summer months and remained high during fall for sites 17,5, 17,6, 17,9, and 17,10 due to low-flow associated with drought conditions. Measurements of pH varied throughout the year due in part to fluctuations in chlorophyll *a* concentrations and storm events. Dissolved solids concentrations showed an increase during summer and fall for sites 17,5, 17,6, 17,9, and 17,10, again due to low-flow effects associated with drought conditions. Total and suspended solids concentrations fluctuated during calendar year 2000 with peaks associated with significant rainfall events (1-2"). Nutrient concentrations exhibited fluctuations throughout calendar year 2000 with increases occurring primarily during the spring and summer months and were most likely associated with application and nutrient runoff at or near the sampling locality. Microbial analyses revealed fluctuations in fecal coliform and enterococci numbers with peaks generally occurring during summer and fall. Yalobusha River had 14 of 18 water quality measurements that were normally (>75%) within acceptable limits of USEPA and MDEQ TMDL guidelines throughout 2000. Total orthophosphate, pH, chlorophyll *a*, and summer fecal coliforms frequently exceeded the guidelines during 2000. See Figure 1 for locations of sampling sites for Yalobusha River. Complete data are available in Figures 17-1 to 17-6, 18-4, and 19-1 to 19-3.

SUMMARY

Water quality parameters were measured for eleven hill land streams and rivers in the Yazoo drainage basin during calendar year 2000 and revealed many expected patterns. Fluctuations in temperature, dissolved oxygen, conductivity, salinity, turbidity, hardness, and alkalinity were often associated with seasonal changes and low-flow drought conditions. Changes in pH were mostly associated with storm events and fluctuations in chlorophyll concentrations. Solids, specifically suspended solids concentrations exhibited fluctuations most frequently occurring with significant storm events (1" or more of rainfall). Peaks in nutrient concentrations were commonly associated with application processes and ensuing nutrient runoff after rainfall events. Observed changes in microbial counts during calendar year 2000 were due primarily to low flows during drought conditions occurring in summer and fall.

Comparisons of water quality data collected during calendar year 2000 and current TMDL guidelines proposed by USEPA (1986) and MDEQ (1999) were made to estimate the acceptability of current water quality parameters and guidelines. Most water quality parameters were consistently within acceptable limits of USEPA and MDEQ TMDL guidelines during calendar year 2000. Non-compliant values frequently occurred (>25% of observations) during calendar year 2000 for total orthophosphate, chlorophyll *a*, and summer (from May to October) fecal coliforms in all eleven streams studied in the Yazoo basin. Eight of eleven streams frequently had pH values that exceeded currently applied MDEQ TMDL guidelines during 2000. Recent developments in pH TMDLs for streams in the north Mississippi loess hill region have led to an alteration in the proposed pH water quality guidelines from 6.5 to 6.0 pH units. With the advent of this

change, many of the watersheds that frequently were non-compliant during calendar year 2000 would, with the new guidelines, be in compliance more than 90% of the time.

Evaluation of water quality during 2000 was performed in hill land watersheds of the Yazoo basin as part of a larger database including habitat, fisheries, benthic invertebrate populations and plant diversity to assess ecosystem health. Specific studies and experiments such as presented in this water quality data characterization are useful in helping to determine potential TMDLs within the Yazoo Basin. Results of the current study show generally good water quality conditions in these watersheds. However, caution should be exercised since the use of data from a single year is considered preliminary and should be evaluated in light of long-term watershed changes. Specific deviations from currently applied water quality standards for these systems might merit more detailed study if they are persistent. Deviations, if attributable to management or land-use conditions, could be remedied through corrective actions. However, as in the case of pH, application of increased knowledge to apparent degraded water quality conditions may lead to other changes in water quality standards for the region.

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Fig. 1. Map of Demonstration Erosion Control (DEC) project watersheds and sampling locations for each watershed during calendar year 2000 (see Note within text for an explanation of watershed identification numbers).

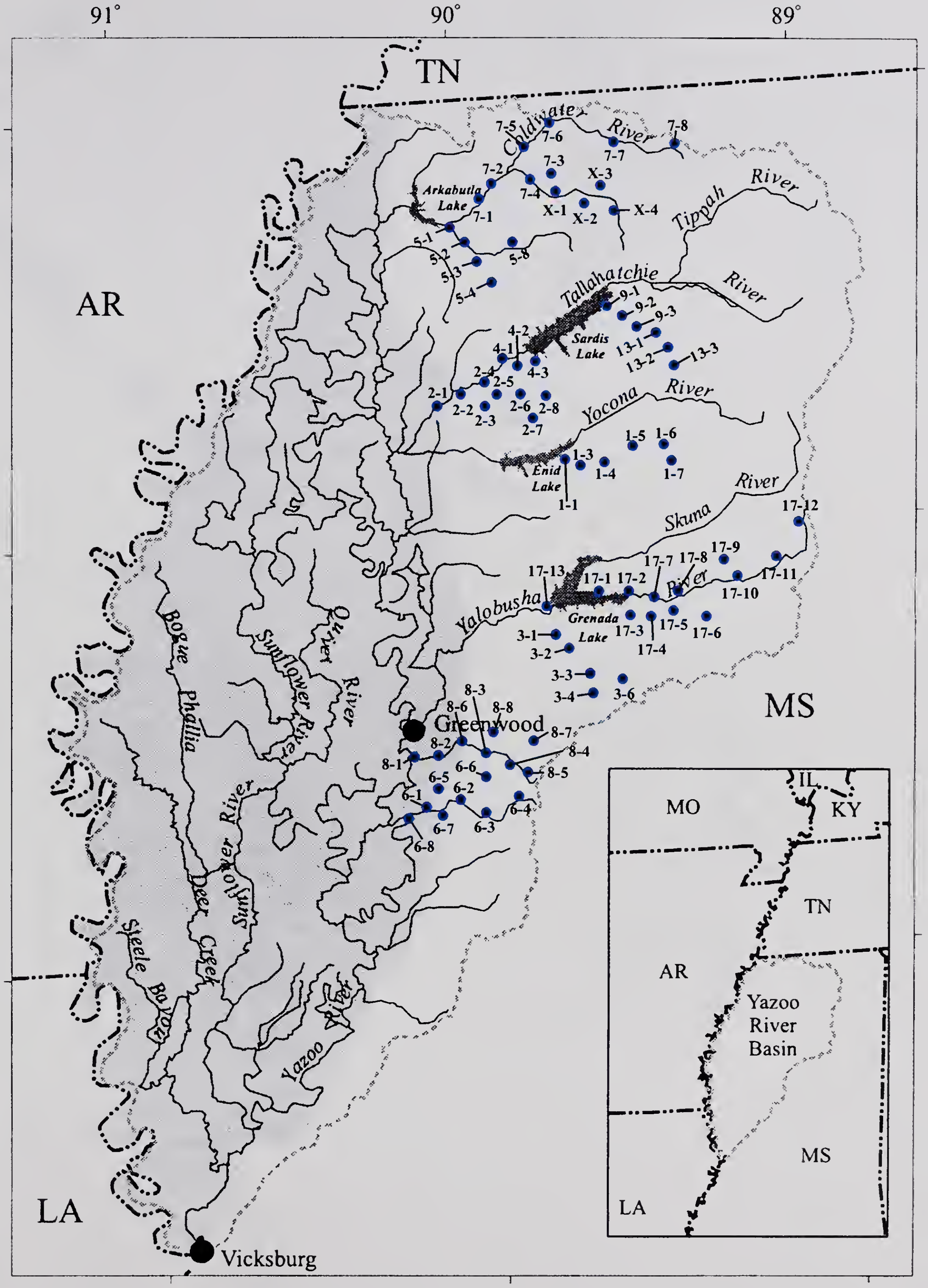


Fig. 1-1. 2000 depth to water, water depth, temperature, and dissolved oxygen measurements for Otoucalofa Creek.

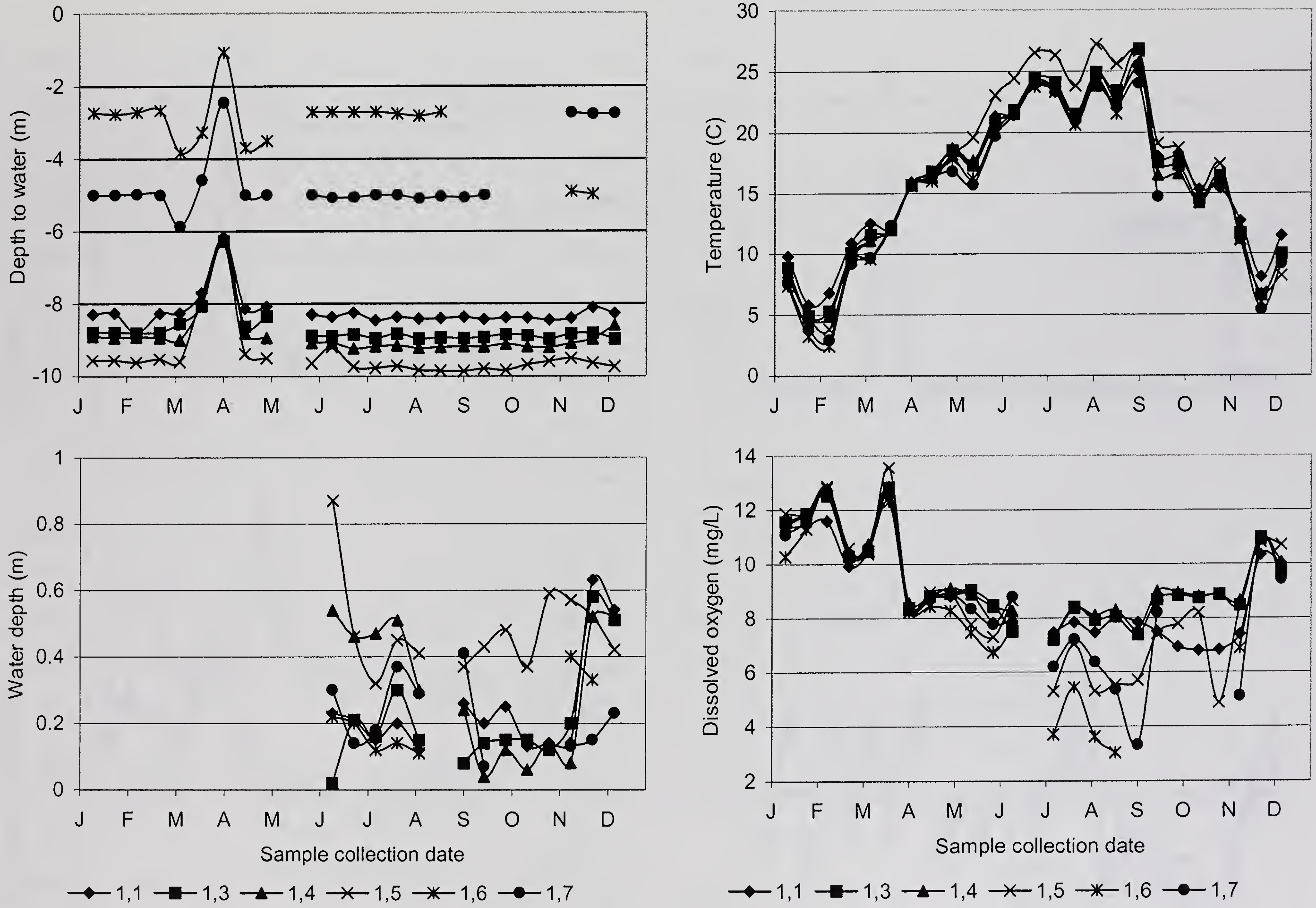


Fig. 1-2. 2000 conductivity, salinity, pH, and turbidity measurements for Otoucalofa Creek.

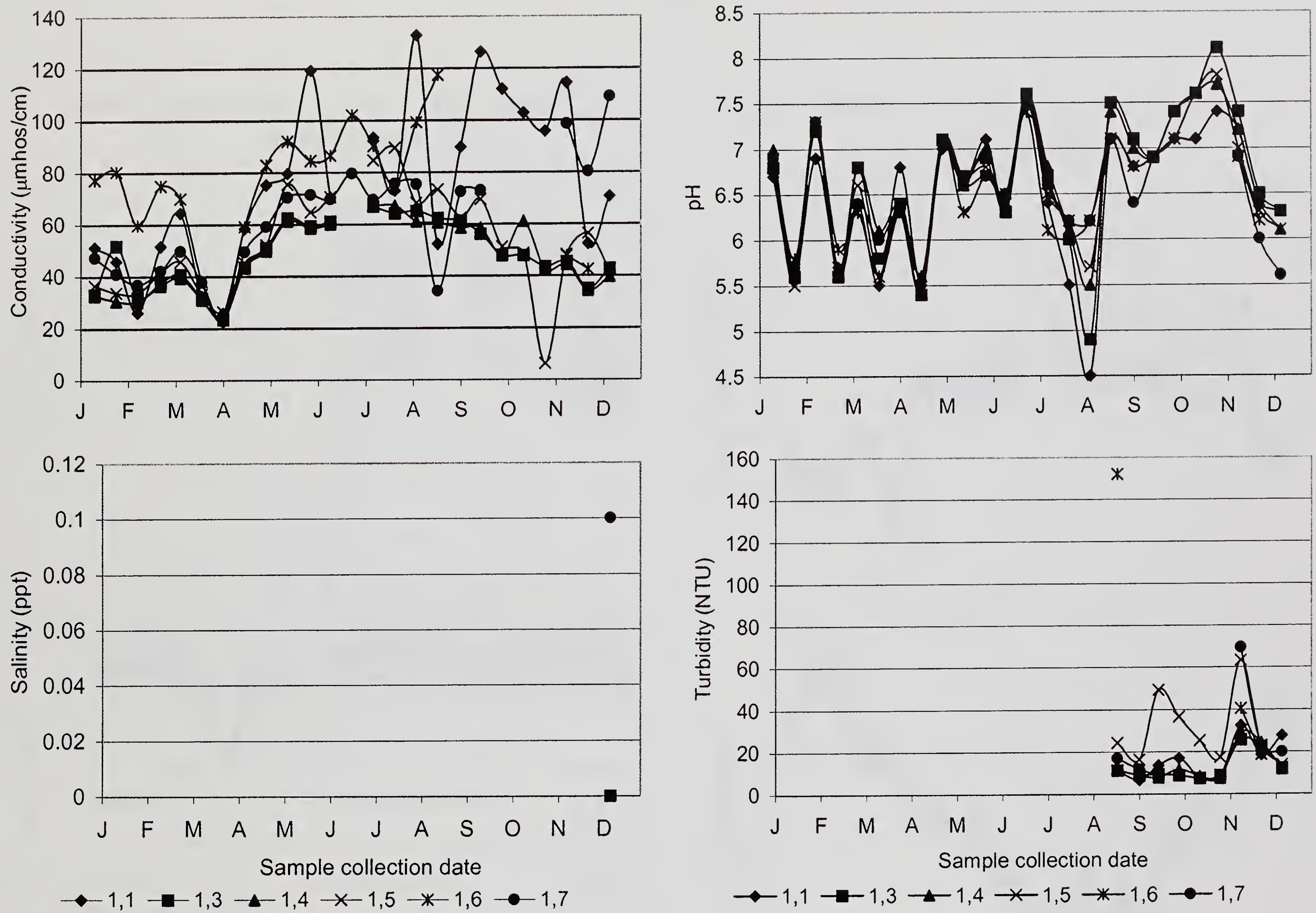


Fig. 1-3. 2000 total, dissolved and suspended solids, and filtered orthophosphate measurements for Otoucalofa Creek.

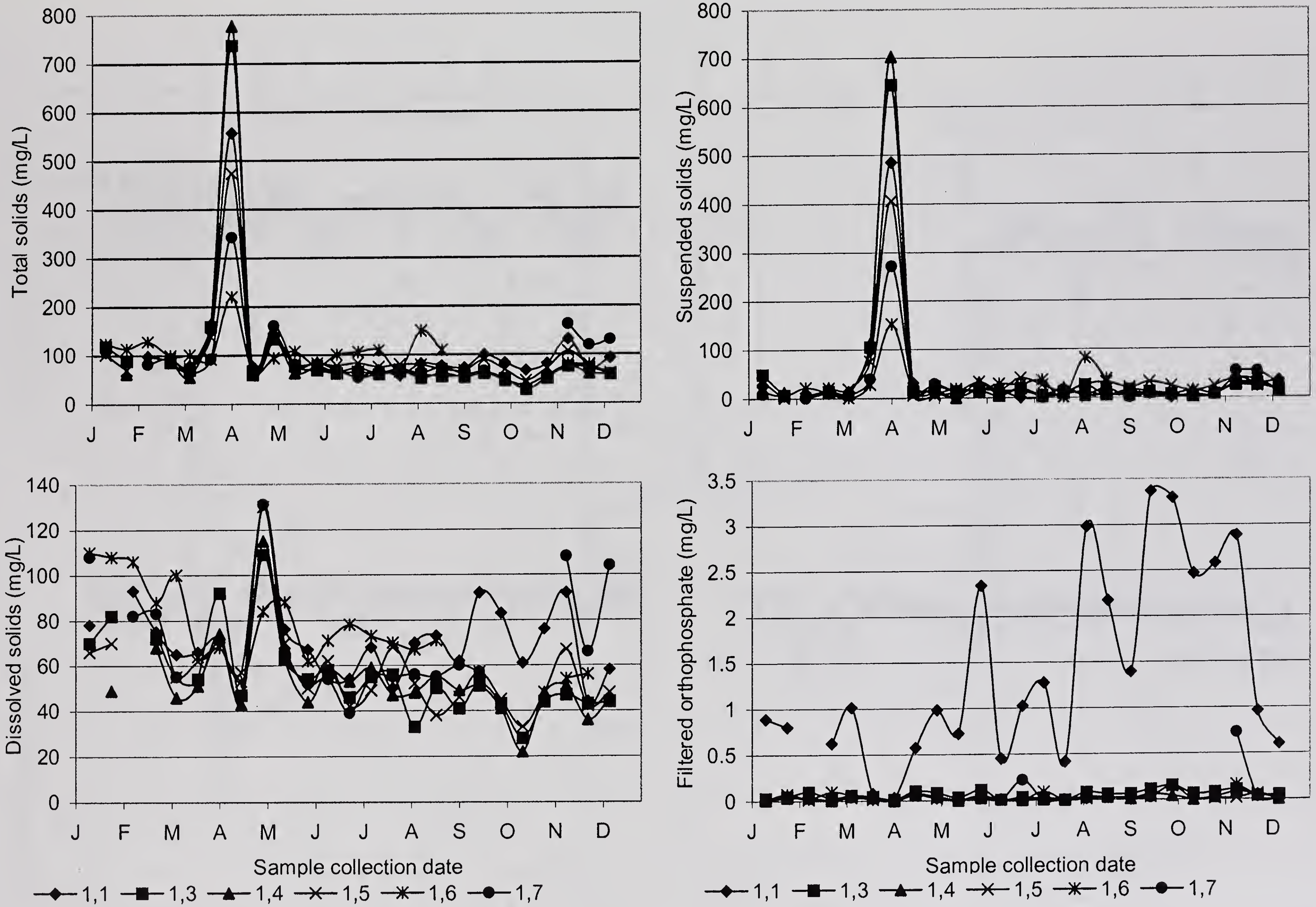


Fig. 1-4. 2000 total orthophosphate, ammonia, nitrate, and total kjeldahl concentrations for Otoucalofa Creek.

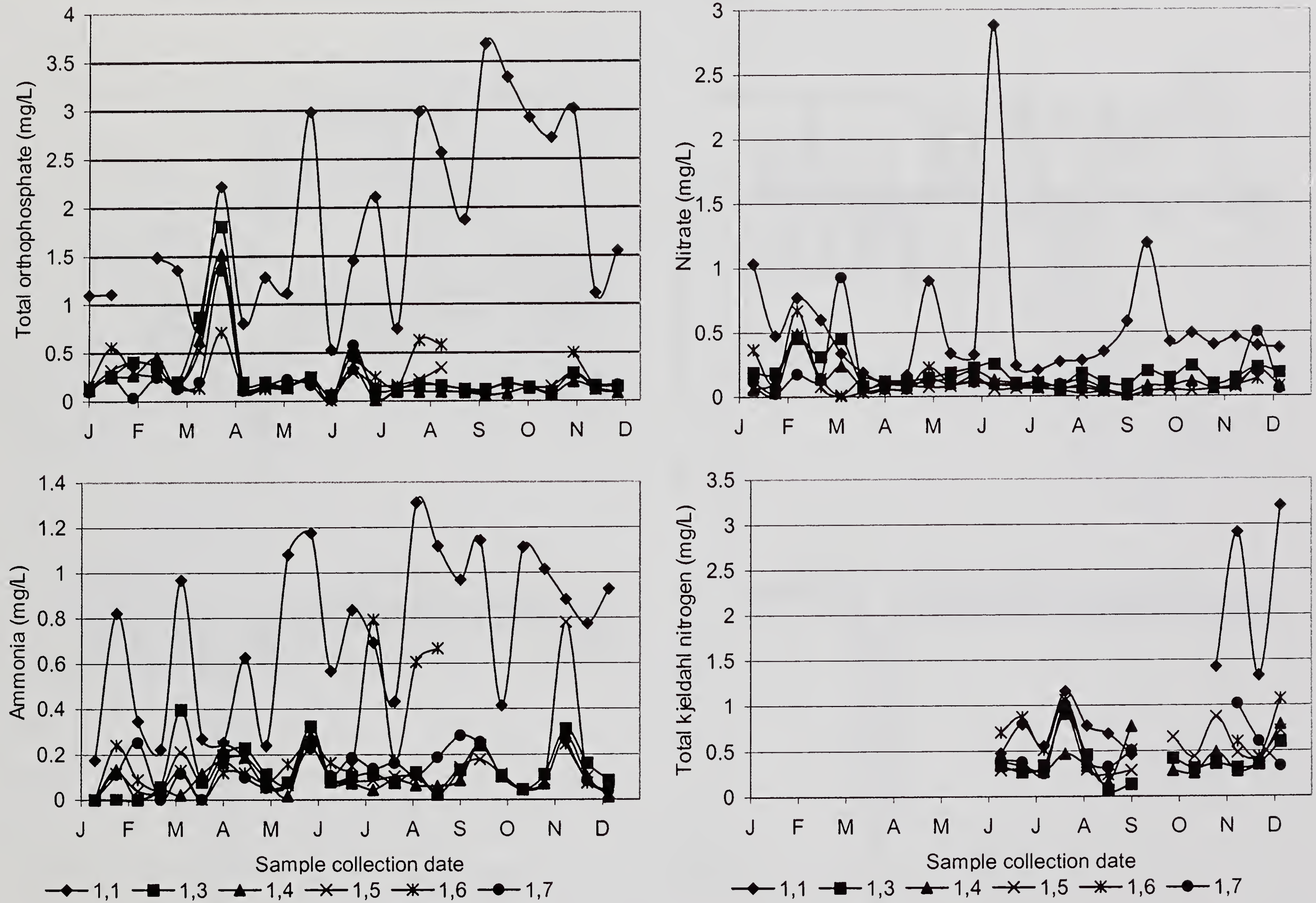


Fig. 1-5. 2000 chlorophyll *a*, fecal coliform and enterococci measurements for Outacolofa Creek.

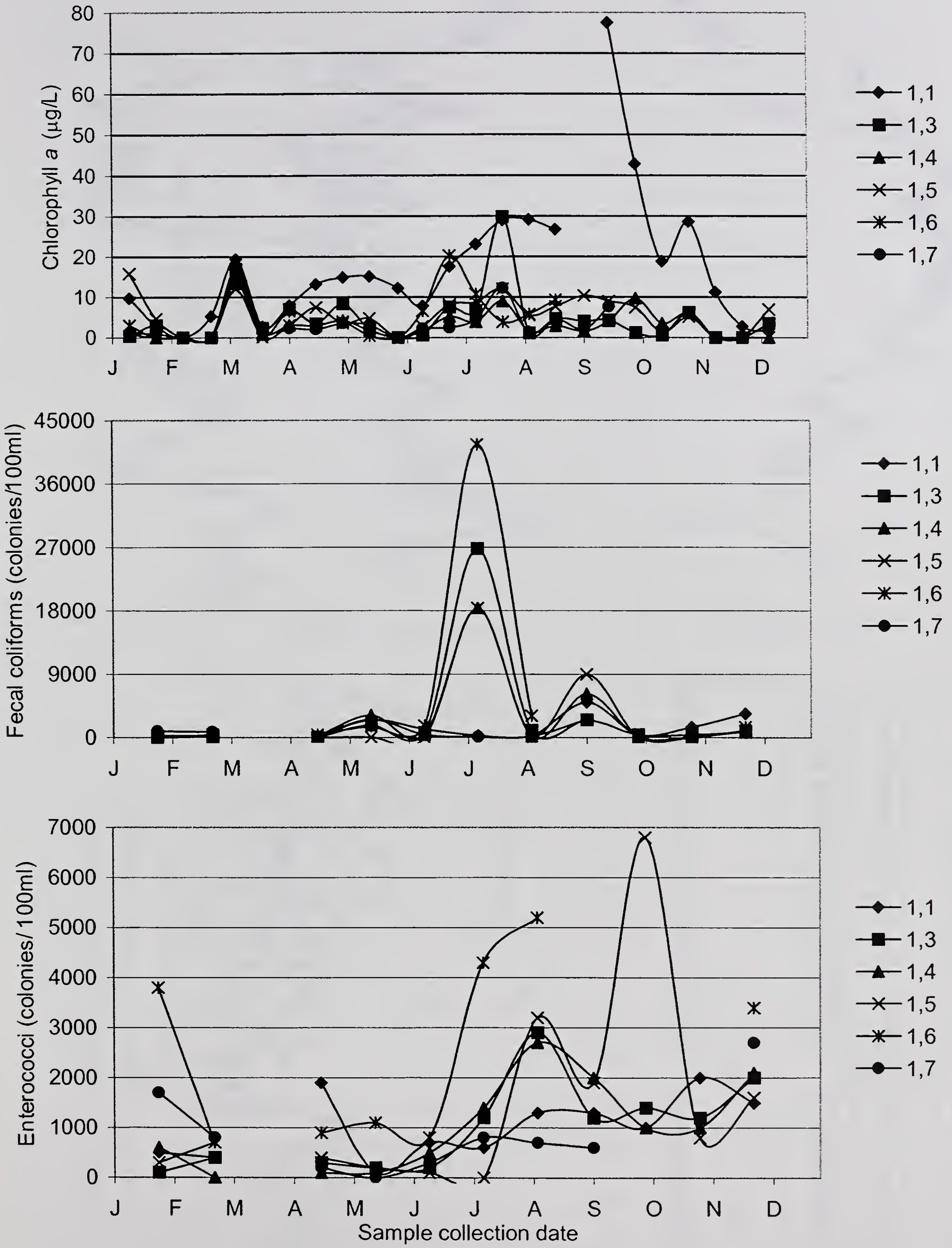


Fig. 2-1. 2000 depth to water, water depth, temperature, and dissolved oxygen measurements for Long Creek.

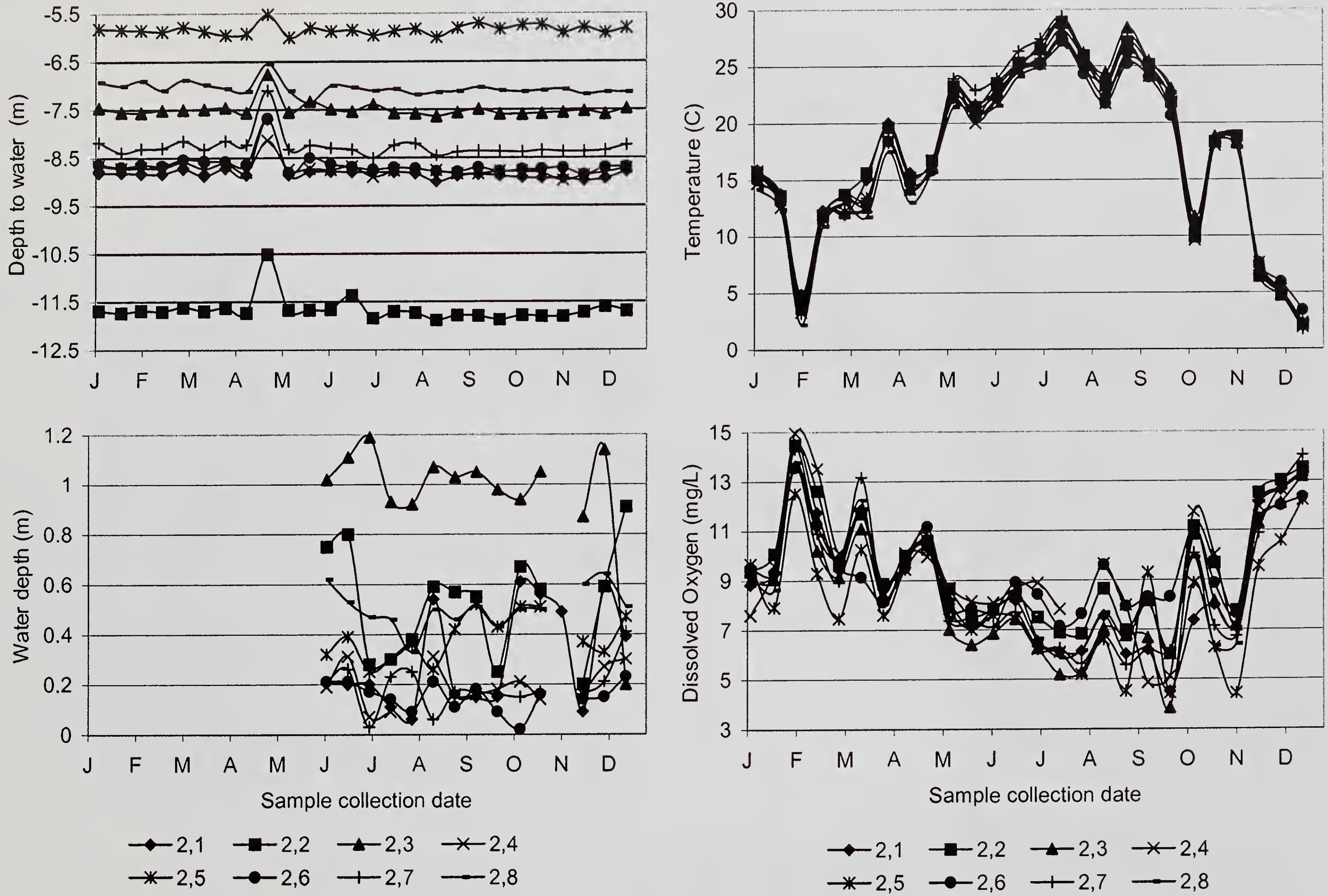


Fig. 2-2. 2000 conductivity, salinity, pH, and hardness measurements for Long Creek.

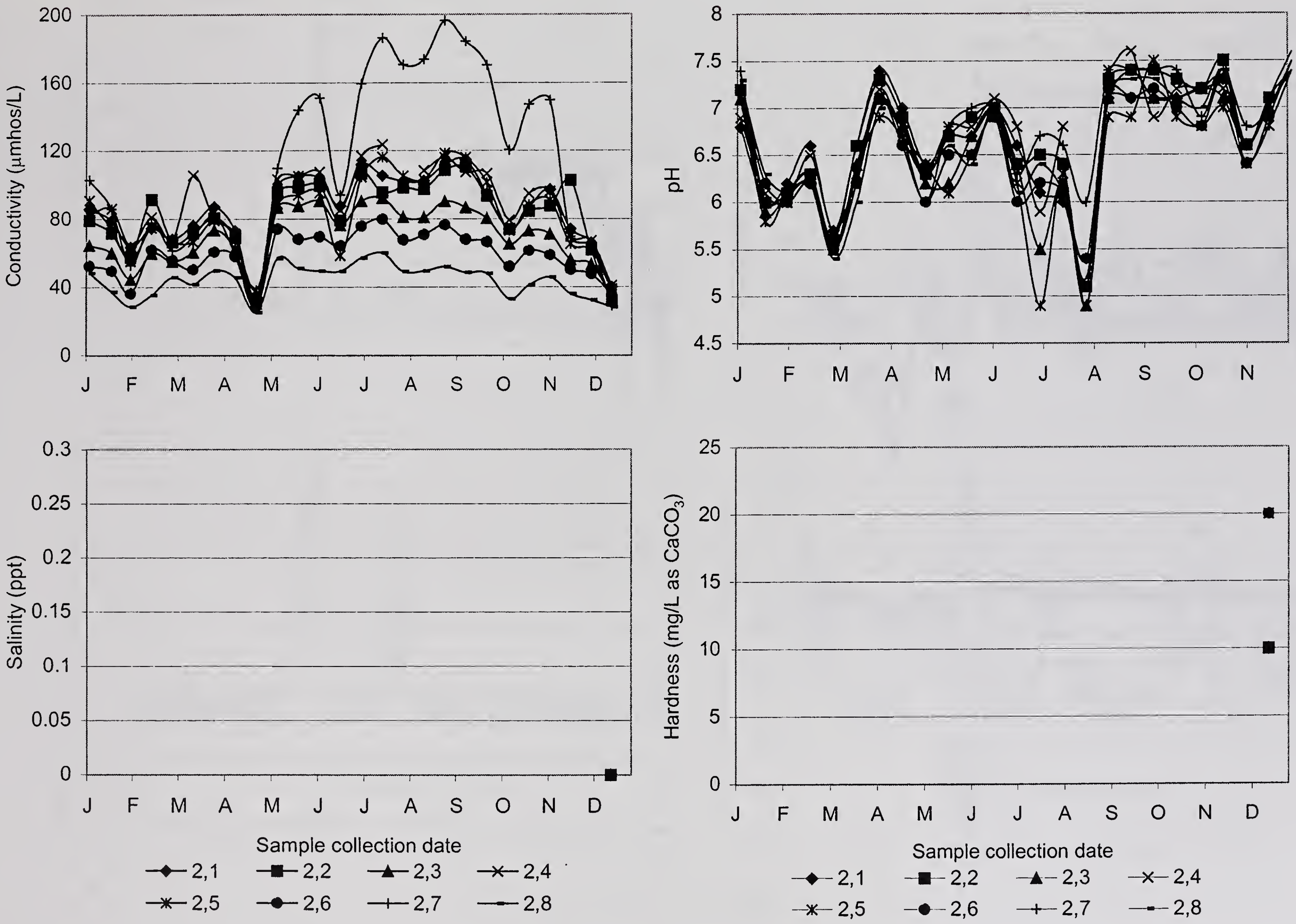


Fig. 2-3. 2000 alkalinity, turbidity, and total and dissolved solids measurments for Long Creek.

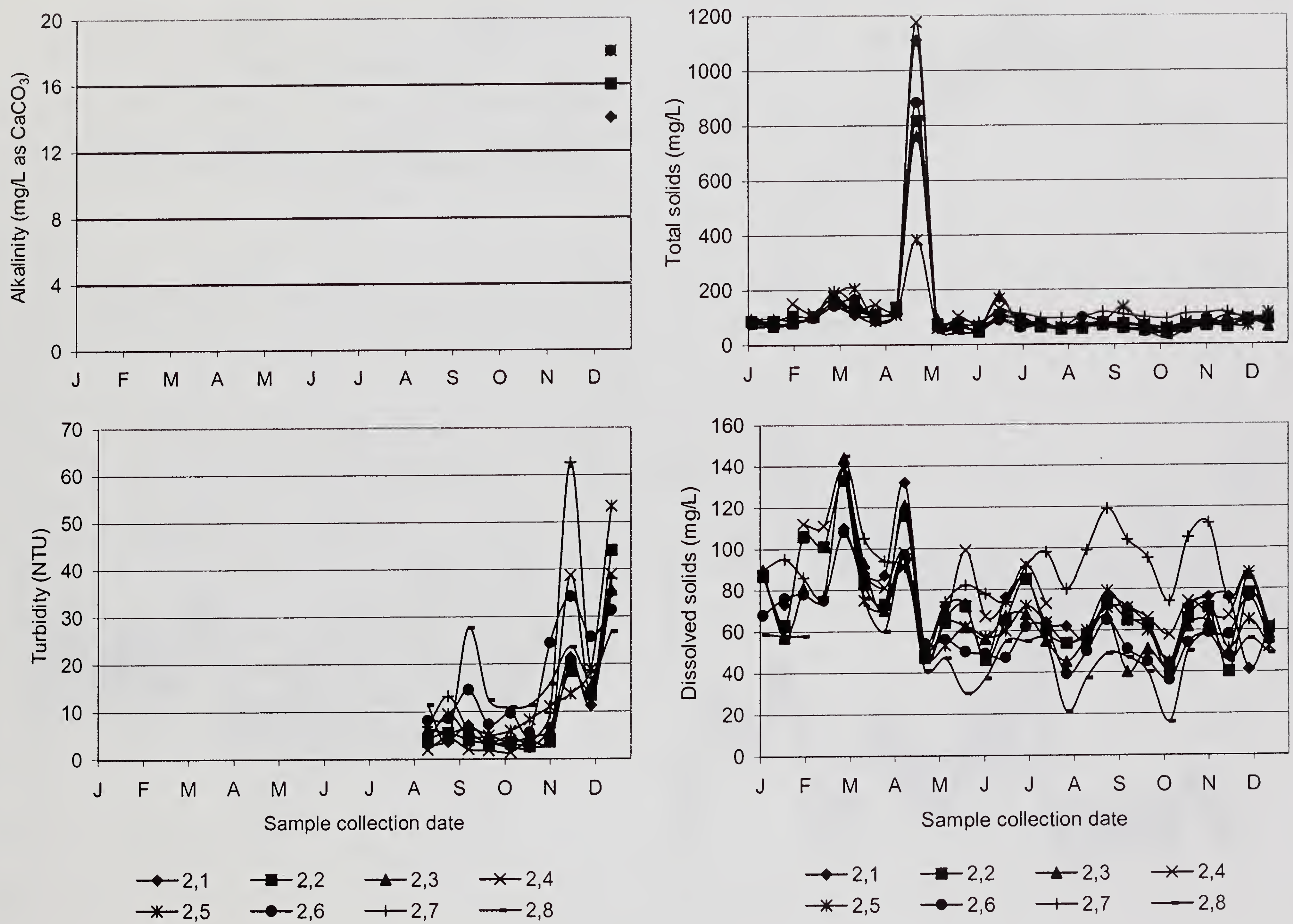


Fig. 2-4. 2000 suspended solids, filtered orthophosphate, total orthophosphate, and ammonia concentrations for Long Creek.

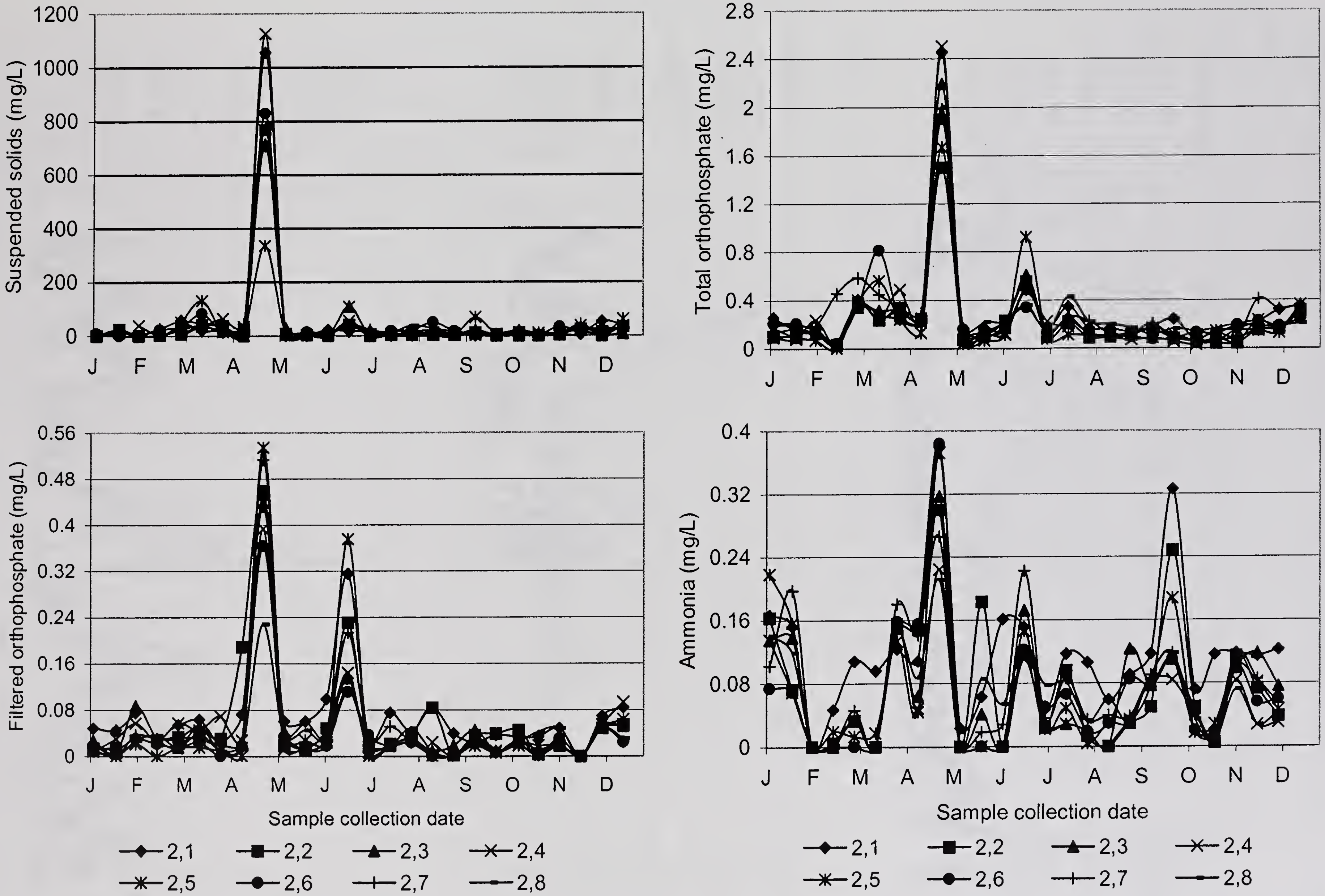
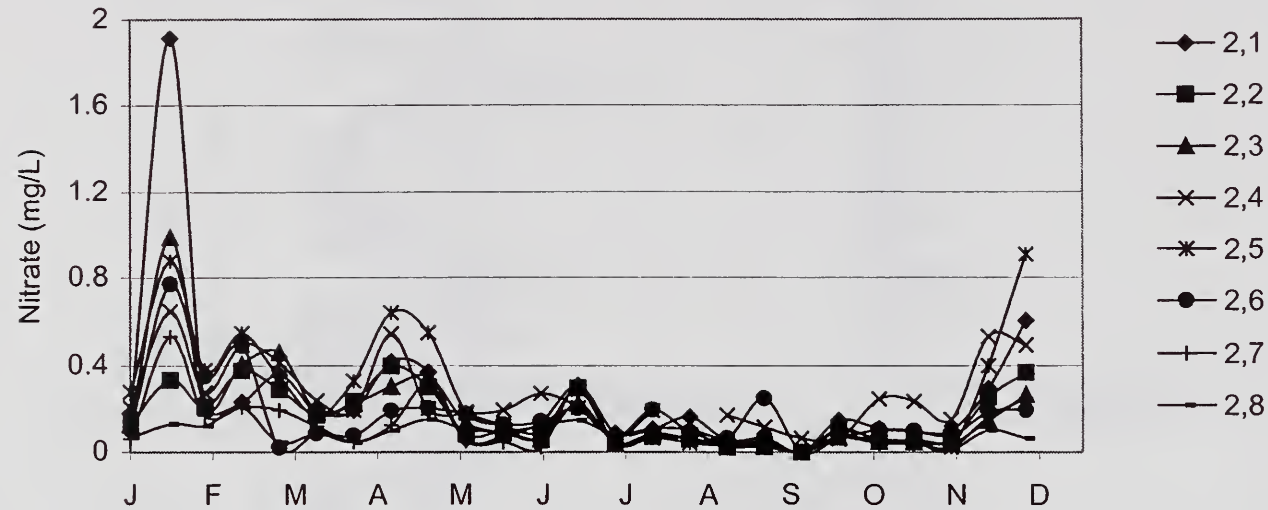
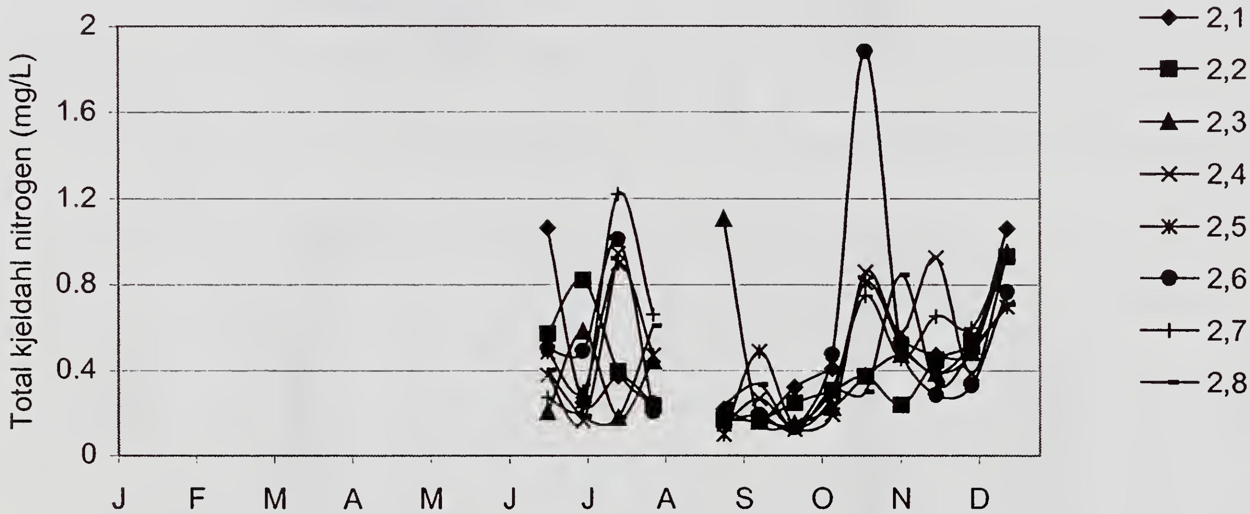


Fig. 2-5. 2000 nitrate, total kjeldahl nitrogen, and chlorophyll *a* concentrations for Long Creek.





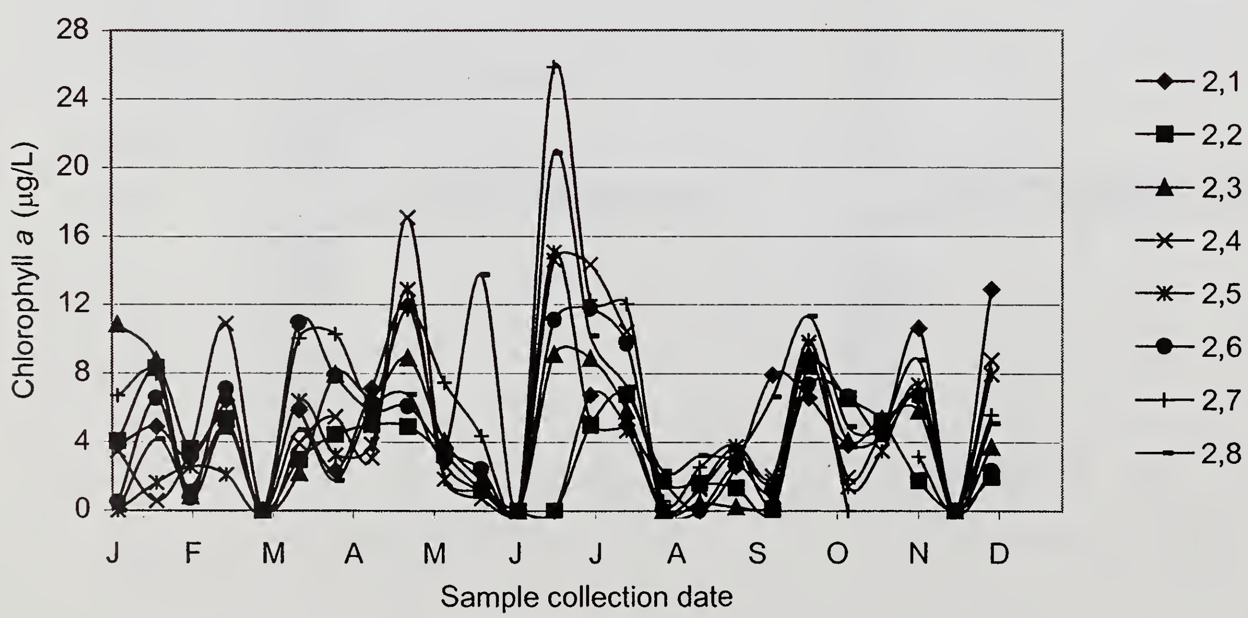


Fig. 2-6. 2000 fecal coliform and enterococci measurements for Long Creek.

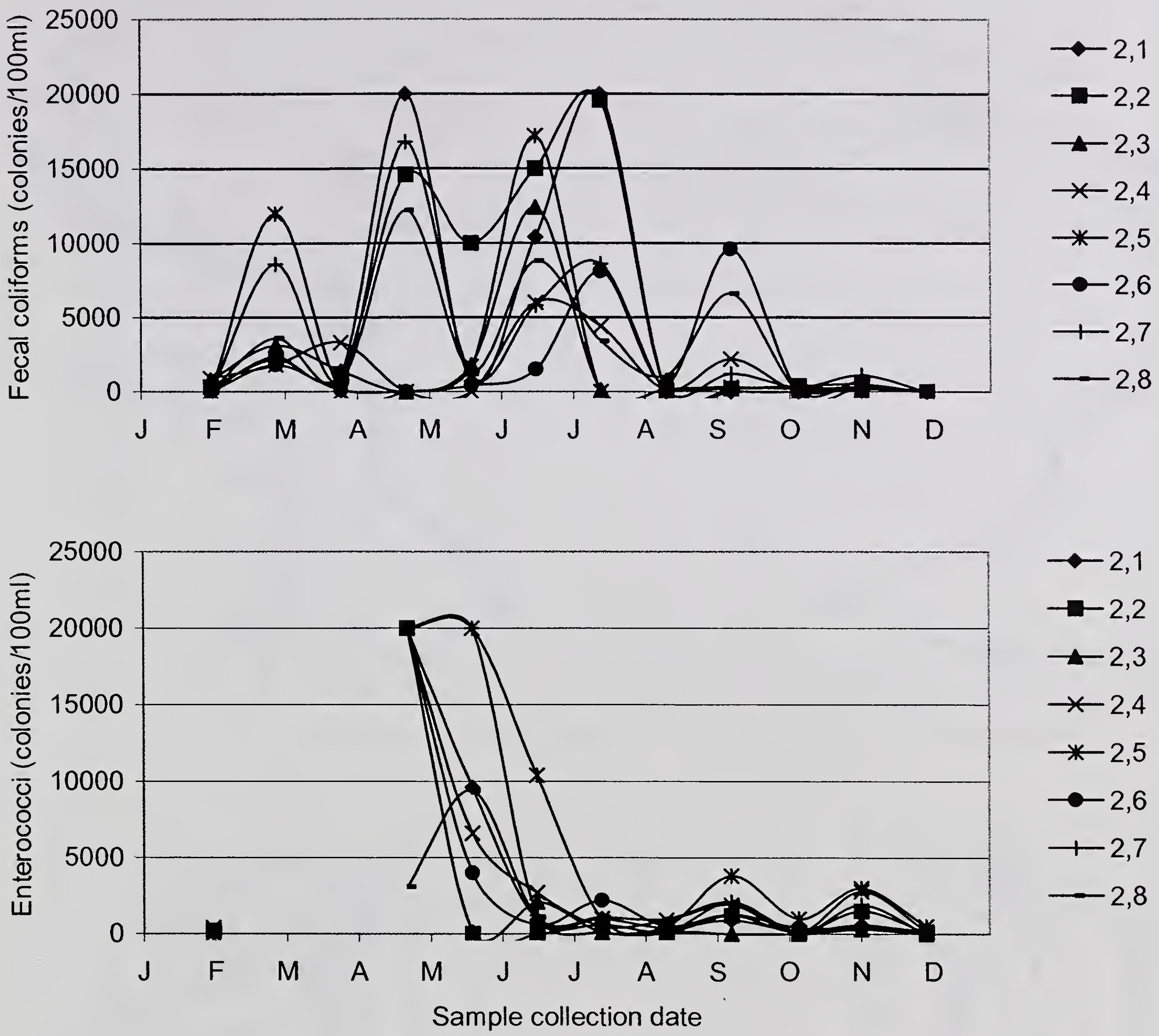


Fig. 3-1. 2000 depth to water, water depth, temperature, and dissolved oxygen measurements for Batupan Bogue Creek.

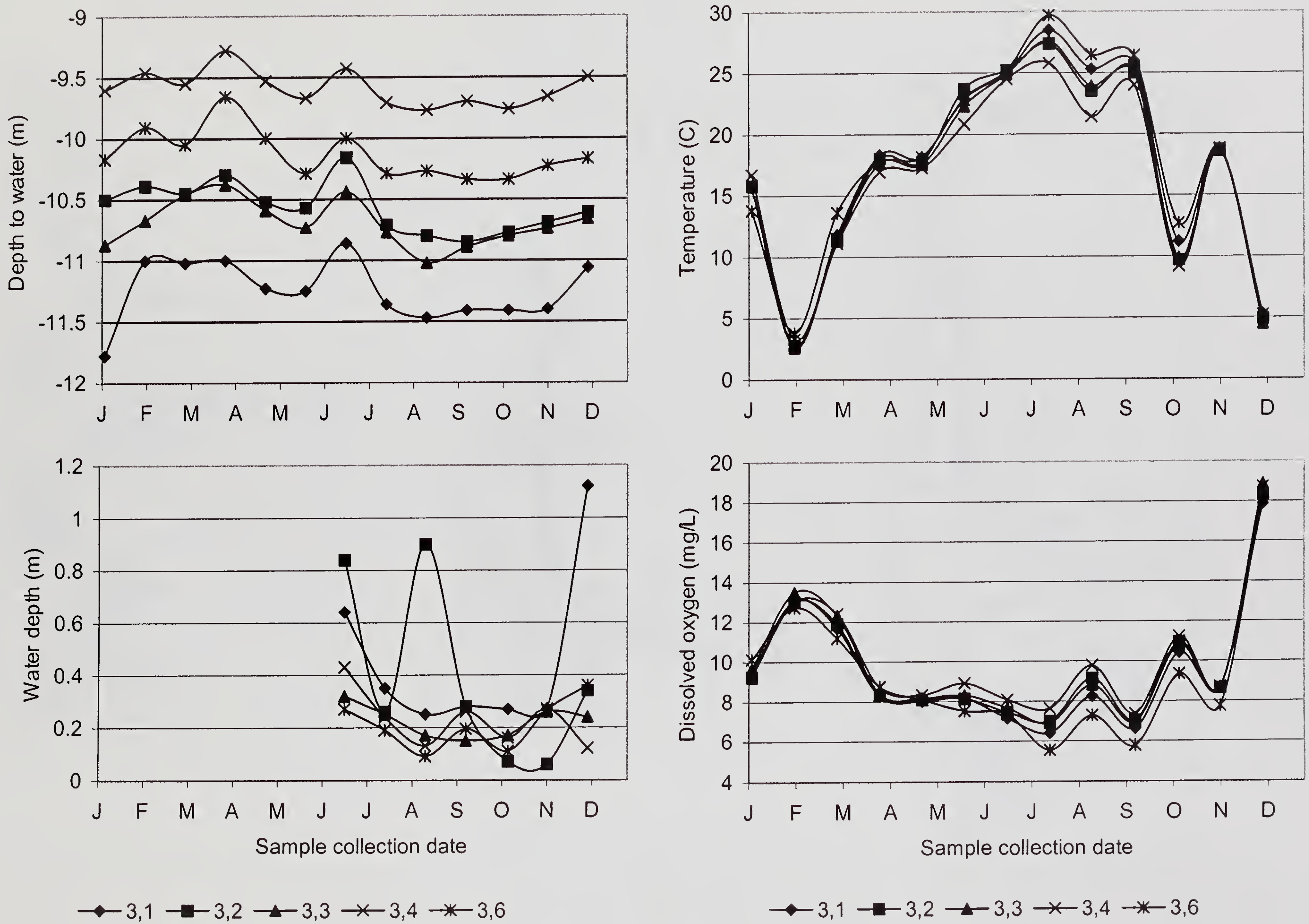


Fig. 3-2. 2000 conductivity, salinity, pH, and turbidity measurements for Batupan Bogue Creek.

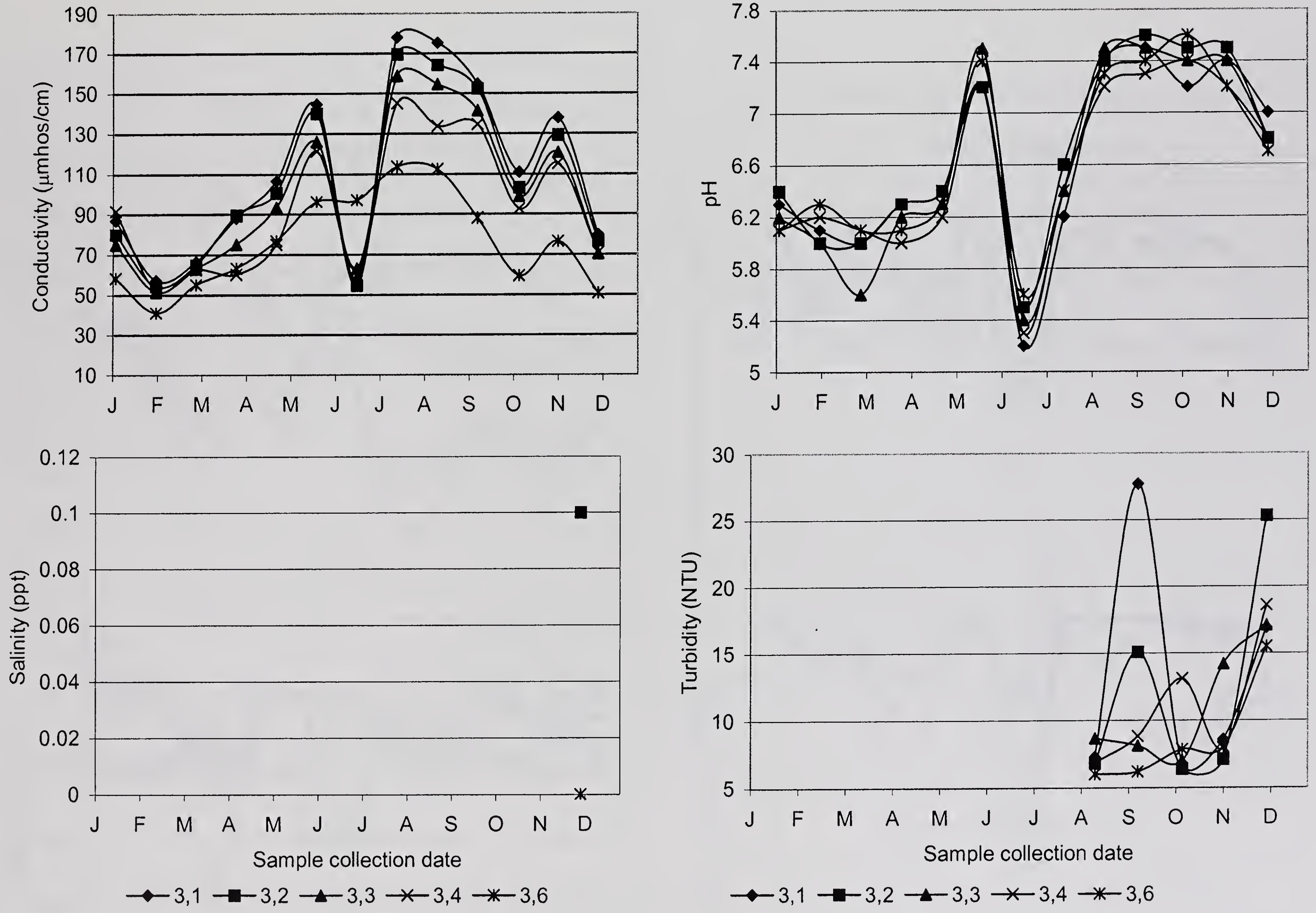


Fig. 3-3. 2000 total, dissolved and suspended solids, and filtered orthophosphate concentraitons for Batupan Bogue Creek.

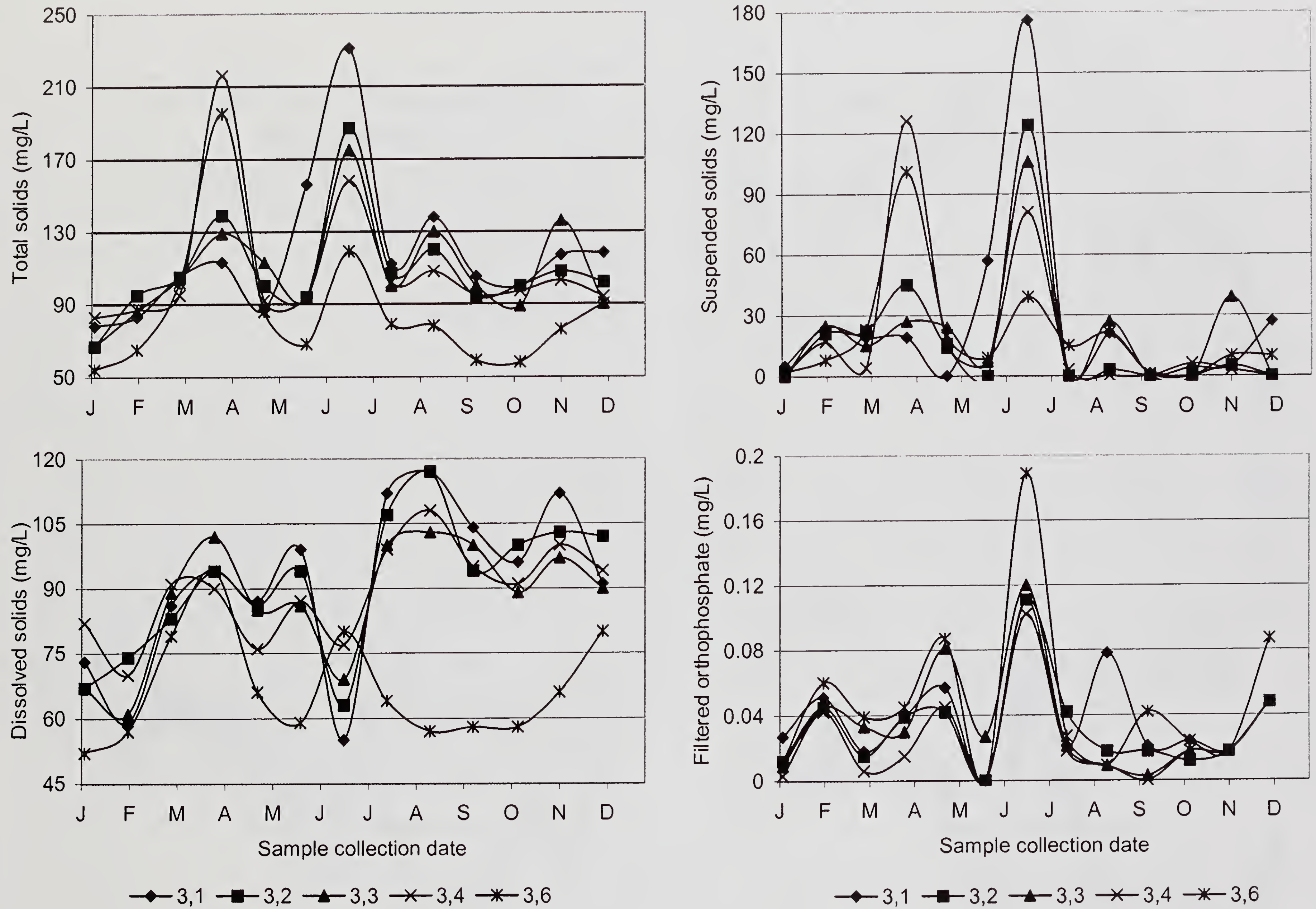


Fig. 3-4. 2000 total orthophosphate, ammonia, nitrate, and total kjeldahl nitrogen concentrations for Batupan Bogue Creek

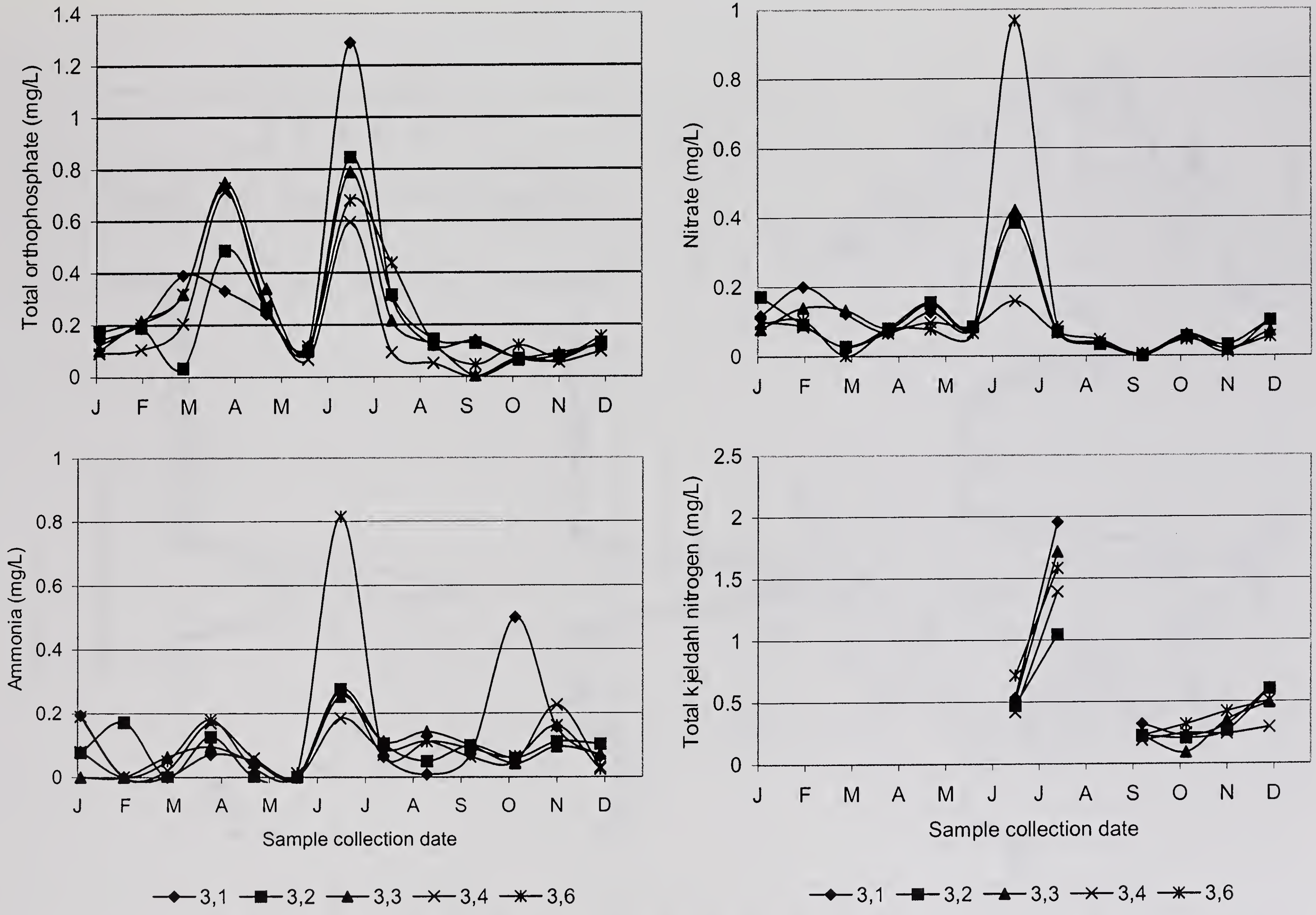


Fig. 3-5. 2000 chlorophyll *a* , fecal coliform, and enterococci measurements for Batupan Bogue Creek.

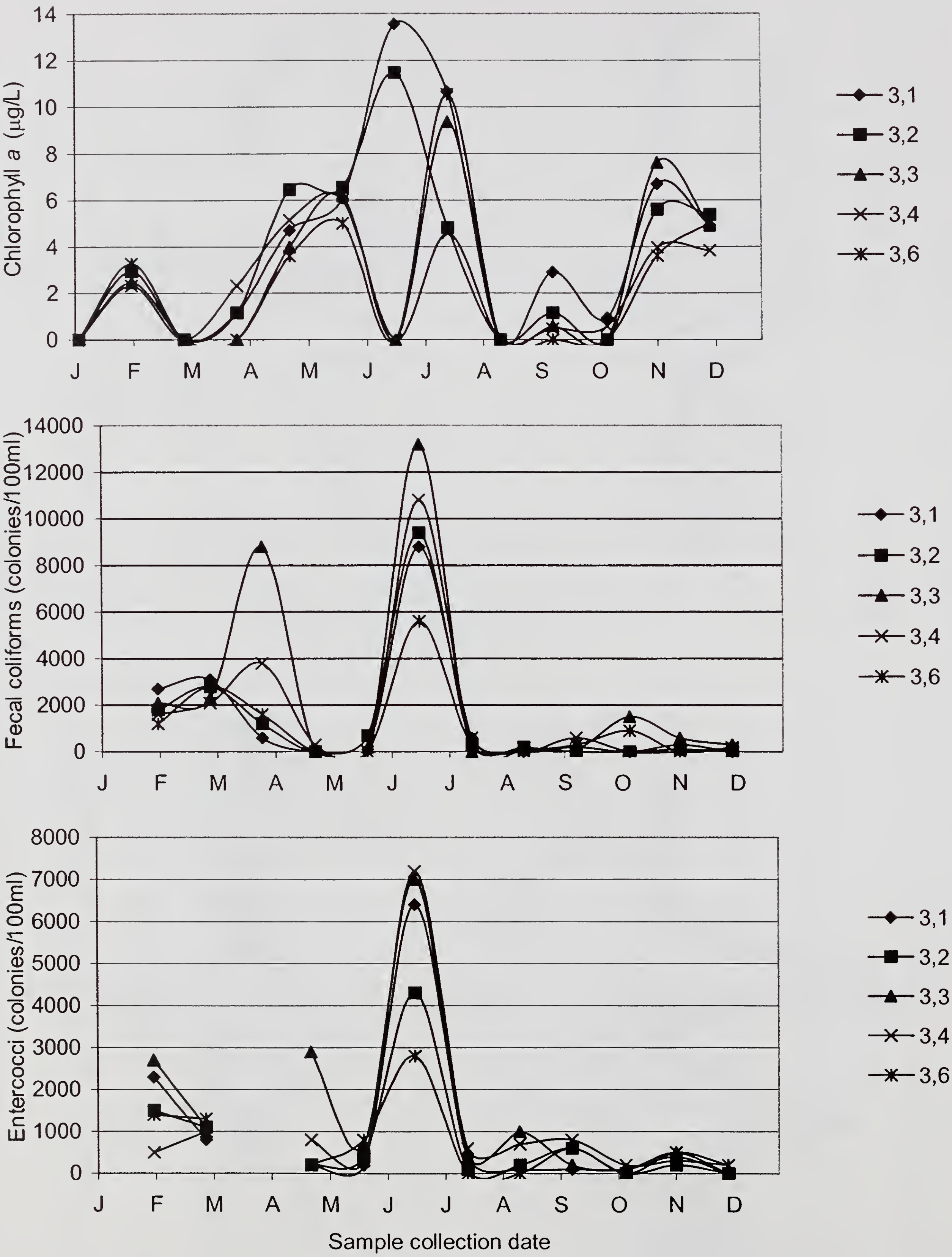


Fig. 4-1. 2000 depth to water, water depth, temperature, and dissolved oxygen measurements for Hotophia Creek.

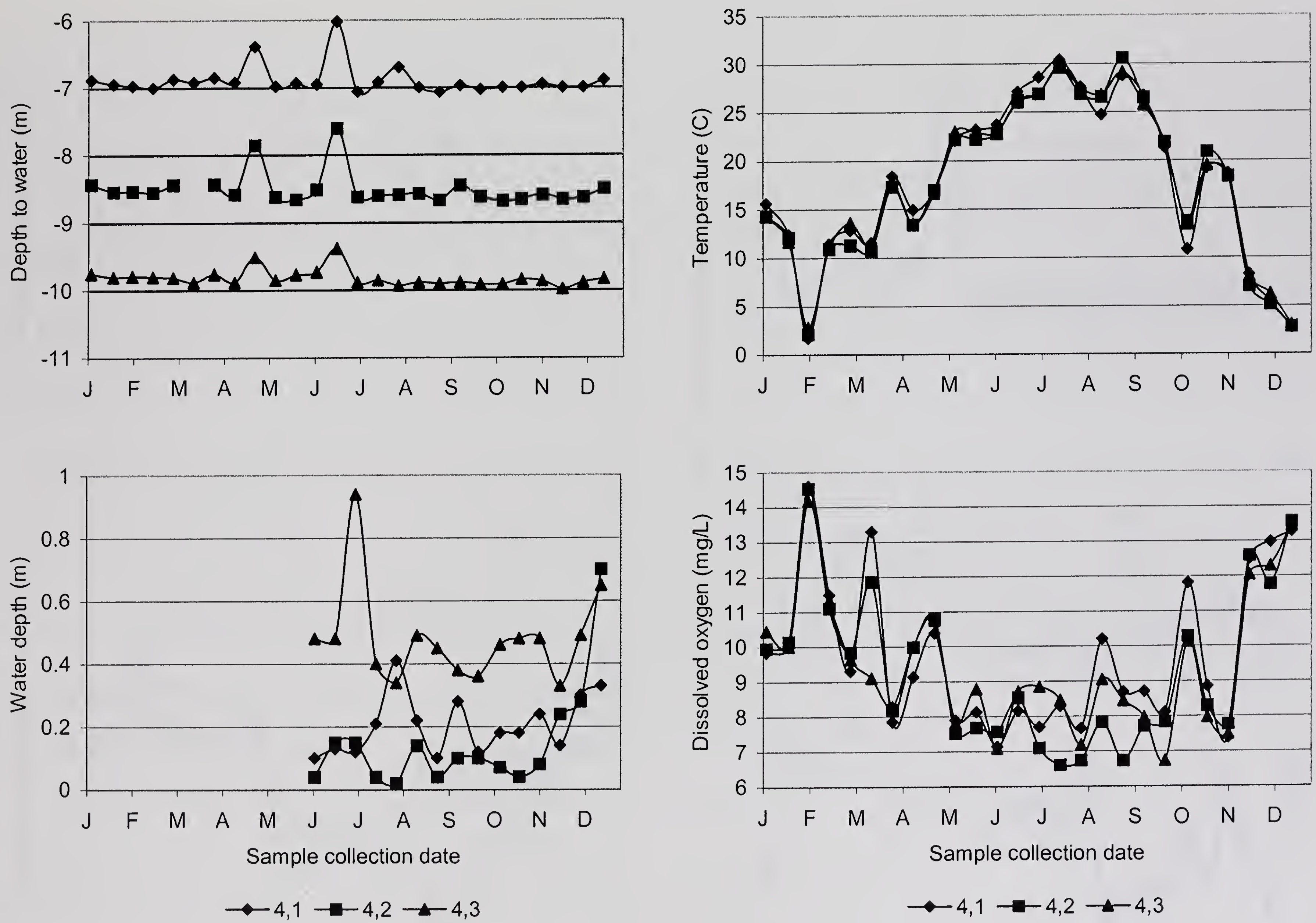


Fig. 4-2. 2000 conductivity, salinity, pH, and hardness measurements for Hotophia Creek.

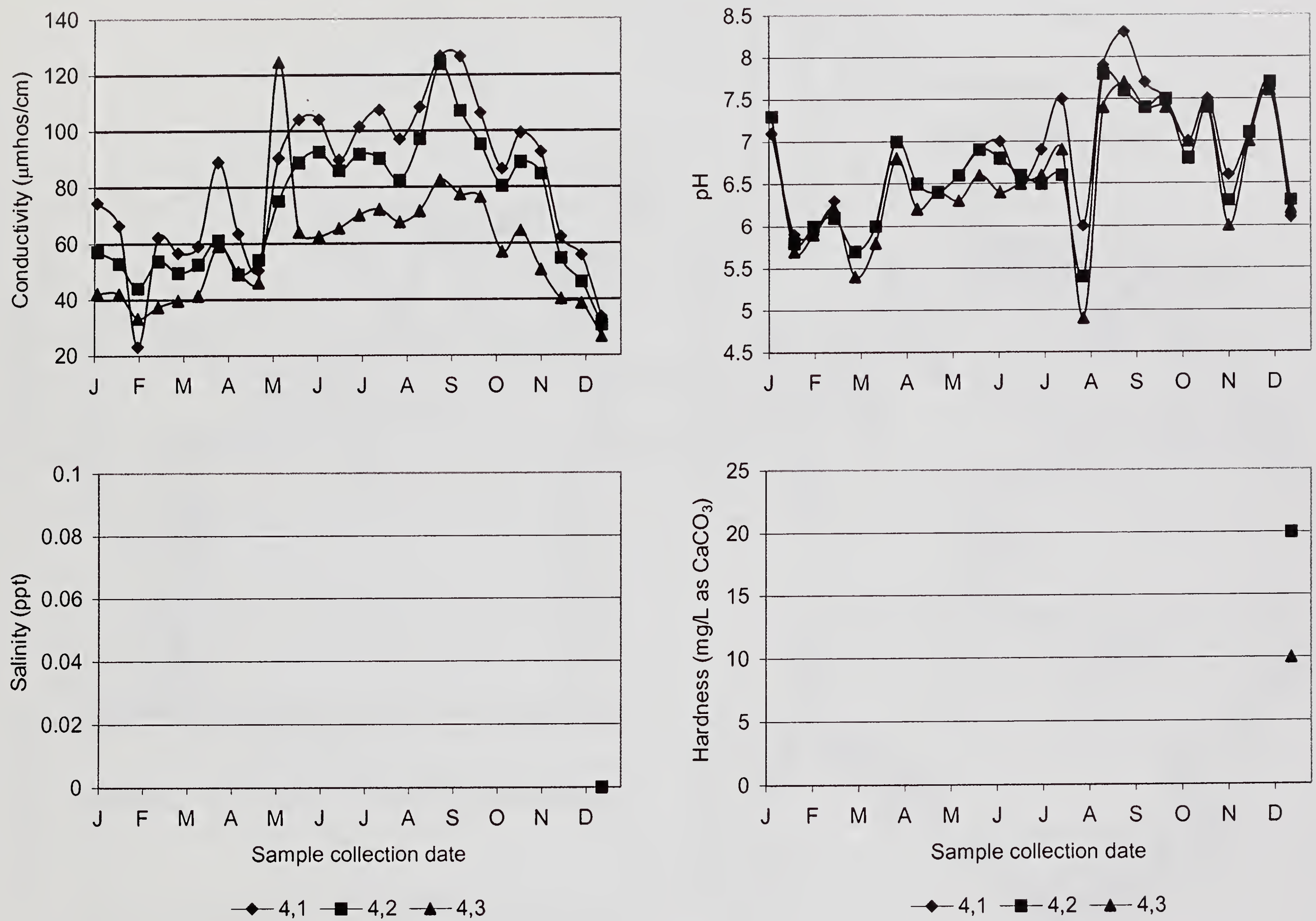


Fig. 4-3. 2000 alkalinity, turbidity, and total and dissolved solids measurements for Hotophia Creek.

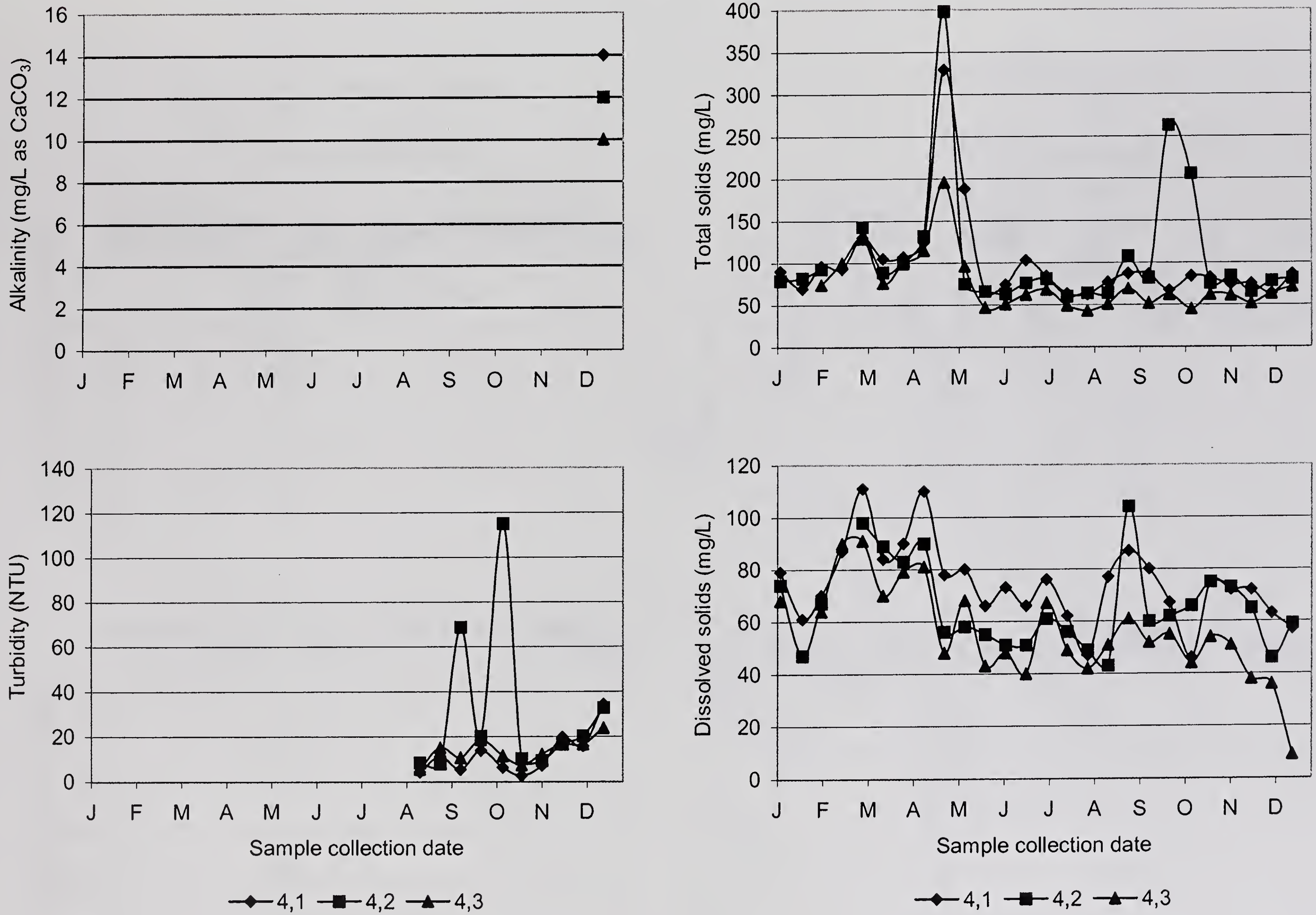


Fig. 4-4. 2000 suspended solids, filtered orthophosphate, total orthophosphate, and ammonia concentrations for Hotophia Creek.

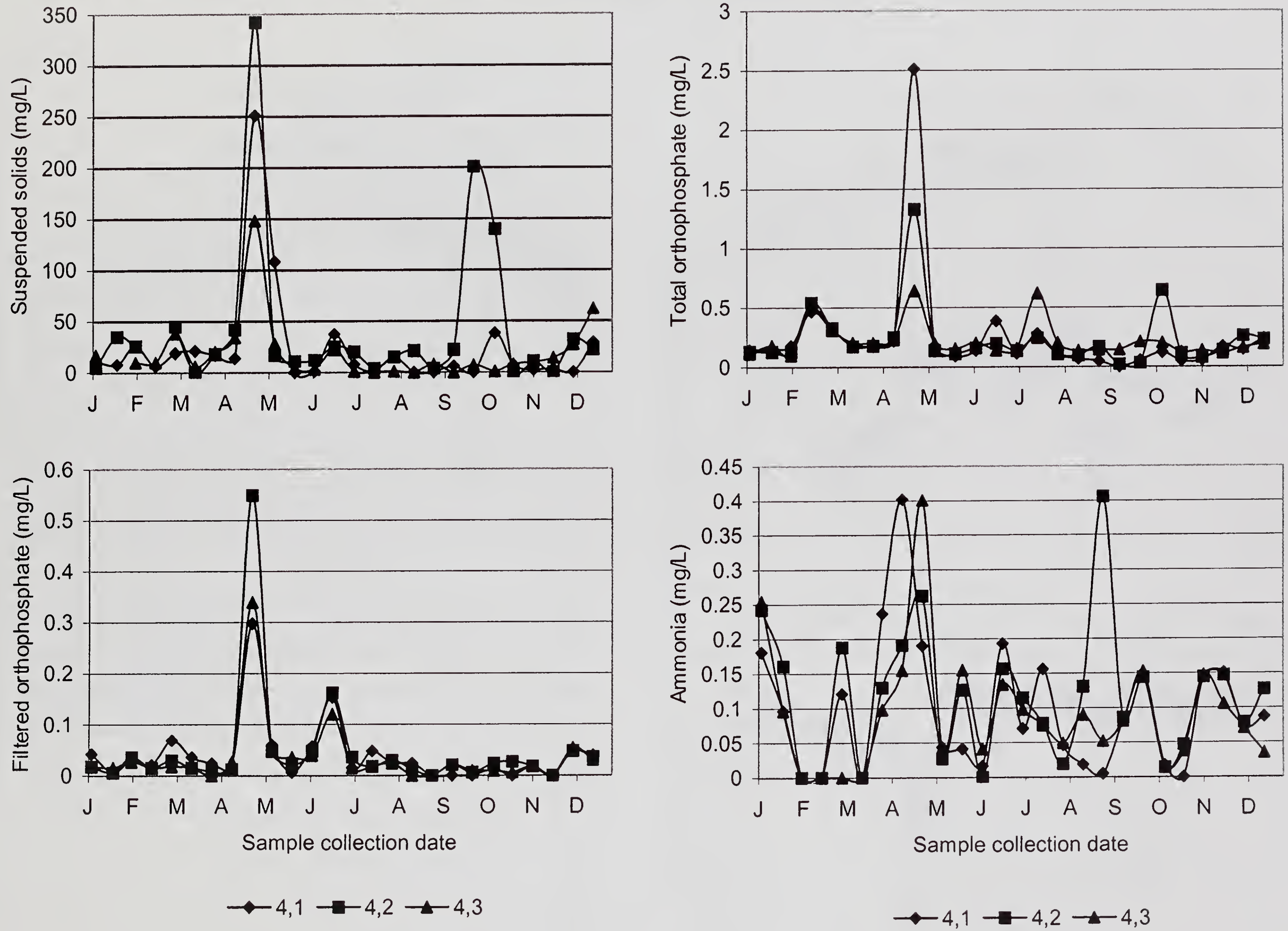


Fig. 4-5. 2000 nitrate, total kjeldahl nitrogen, and chlorophyll *a* concentrations for Hotophia Creek.

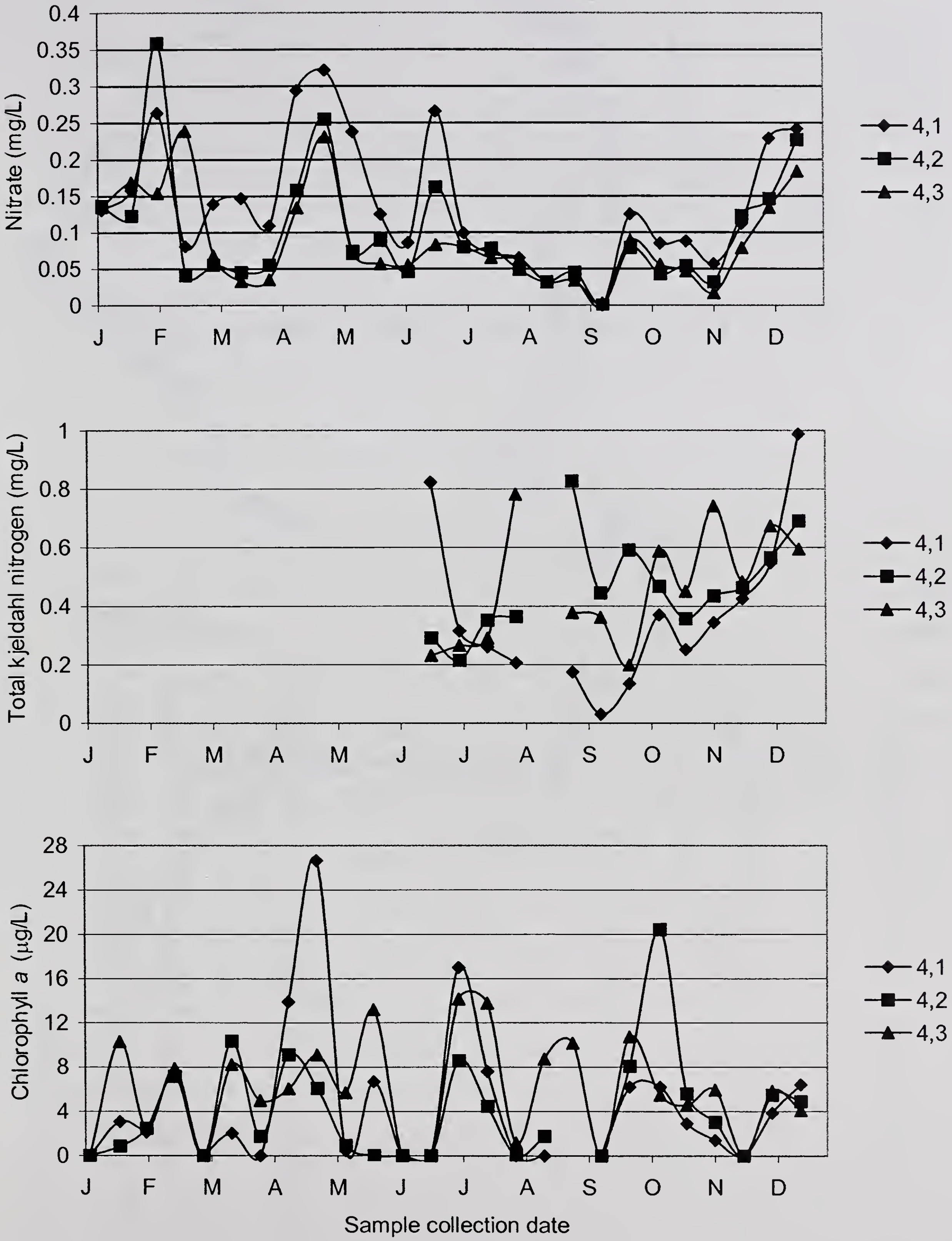
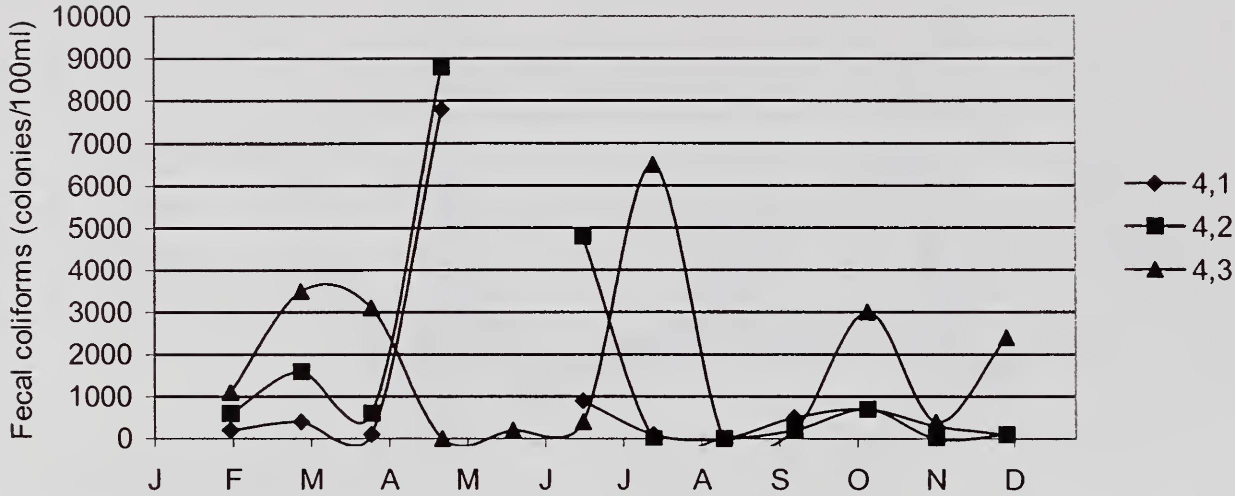


Fig. 4-6. 2000 fecal coliform and enterococci measurements for Hotophia Creek.



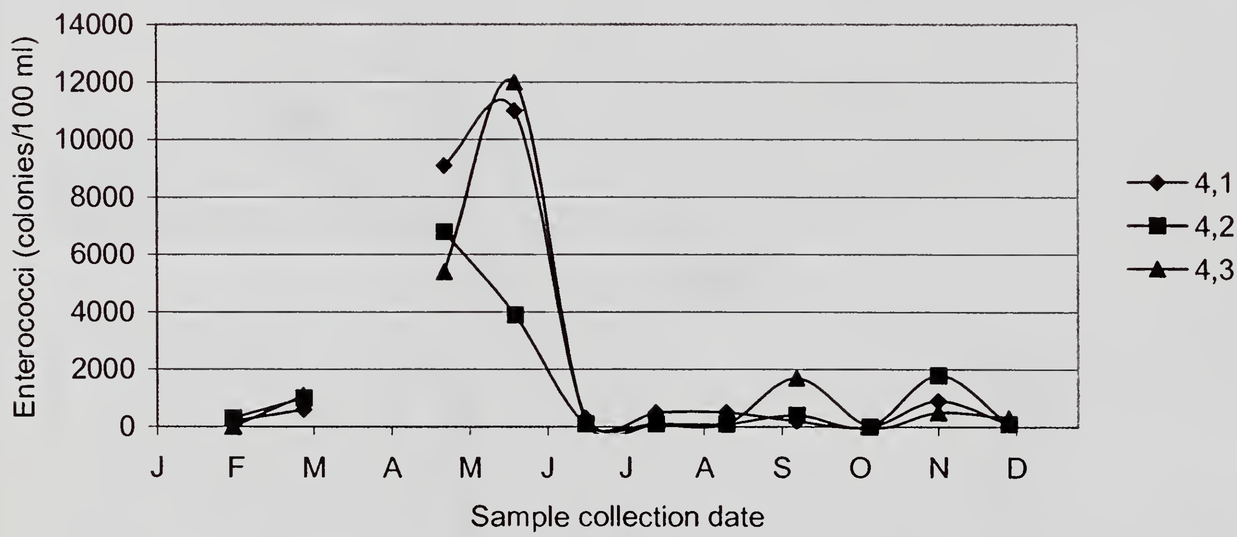


Fig. 5-1. 2000 depth to water, water depth, temperature, and dissolved oxygen measurements for Hickahala Creek.

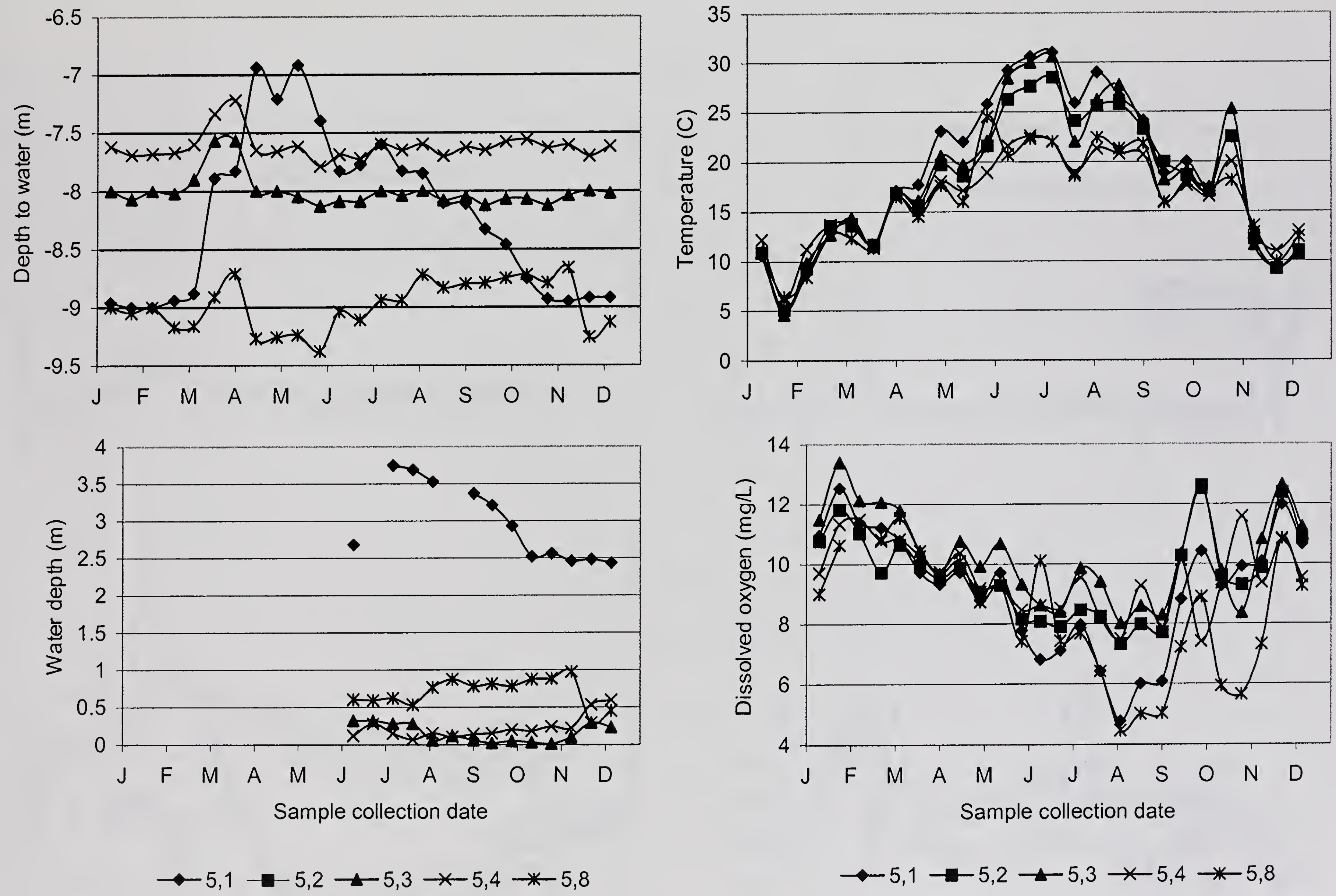


Fig. 5-2. 2000 conductivity, salinity, pH, and turbidity measurements for Hickahala Creek.

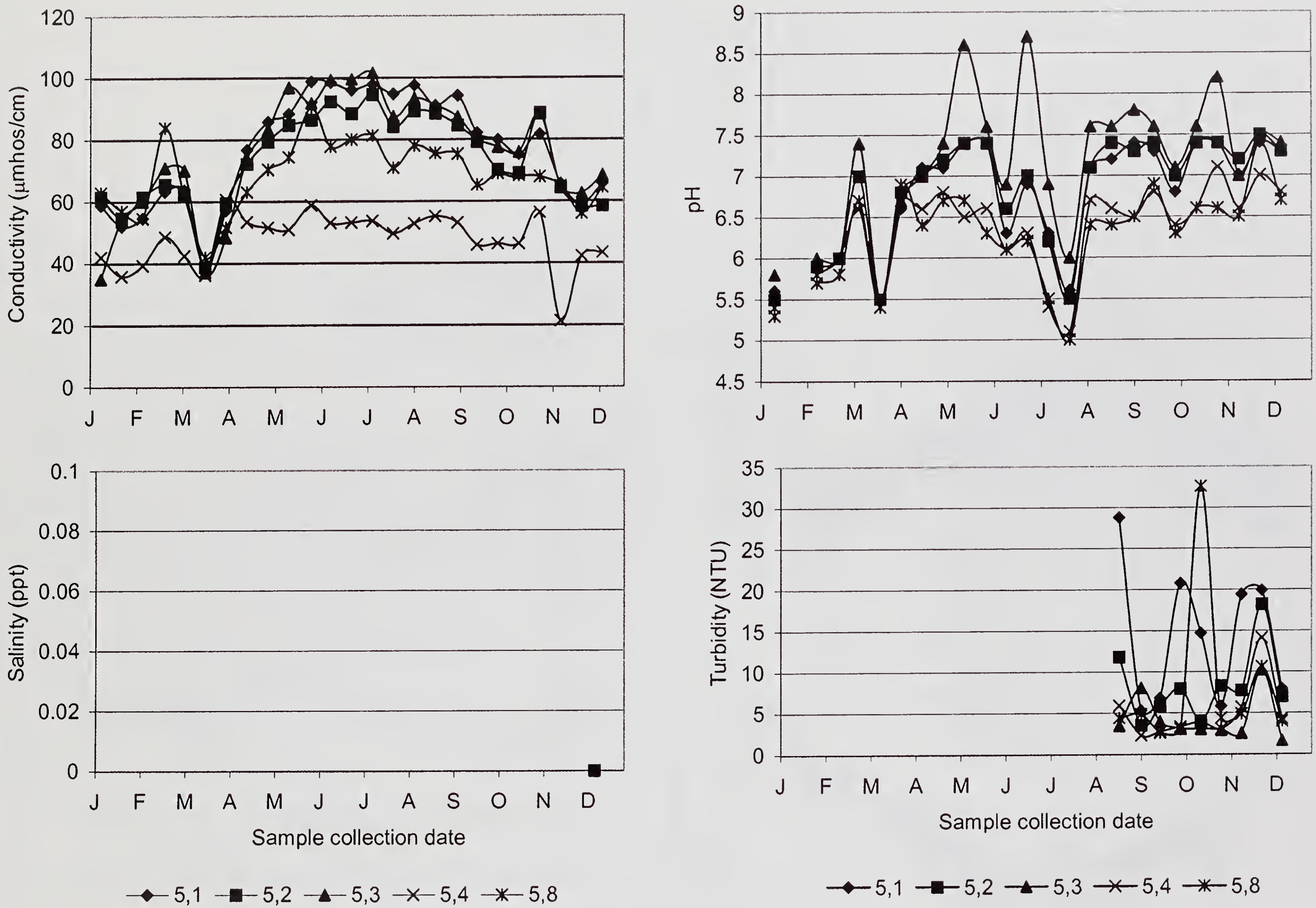


Fig. 5-3. 2000 total, dissolved and suspended solids, and filtered orthophosphate concentrations for Hickahala Creek.

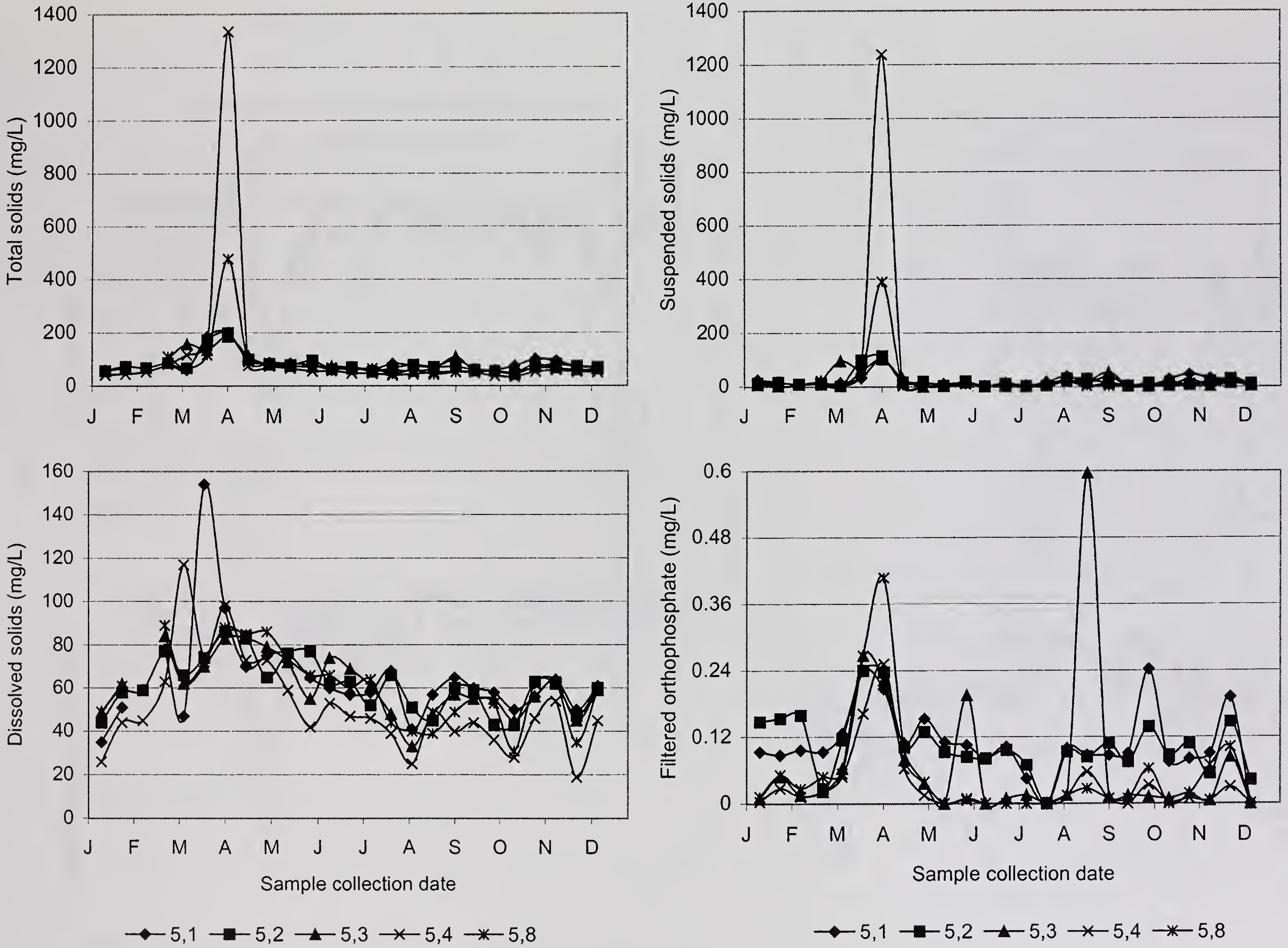


Fig. 5-4. 2000 total orthophosphate, ammonia, nitrate, and total kjeldahl nitrogen concentrations for Hickahala Creek.

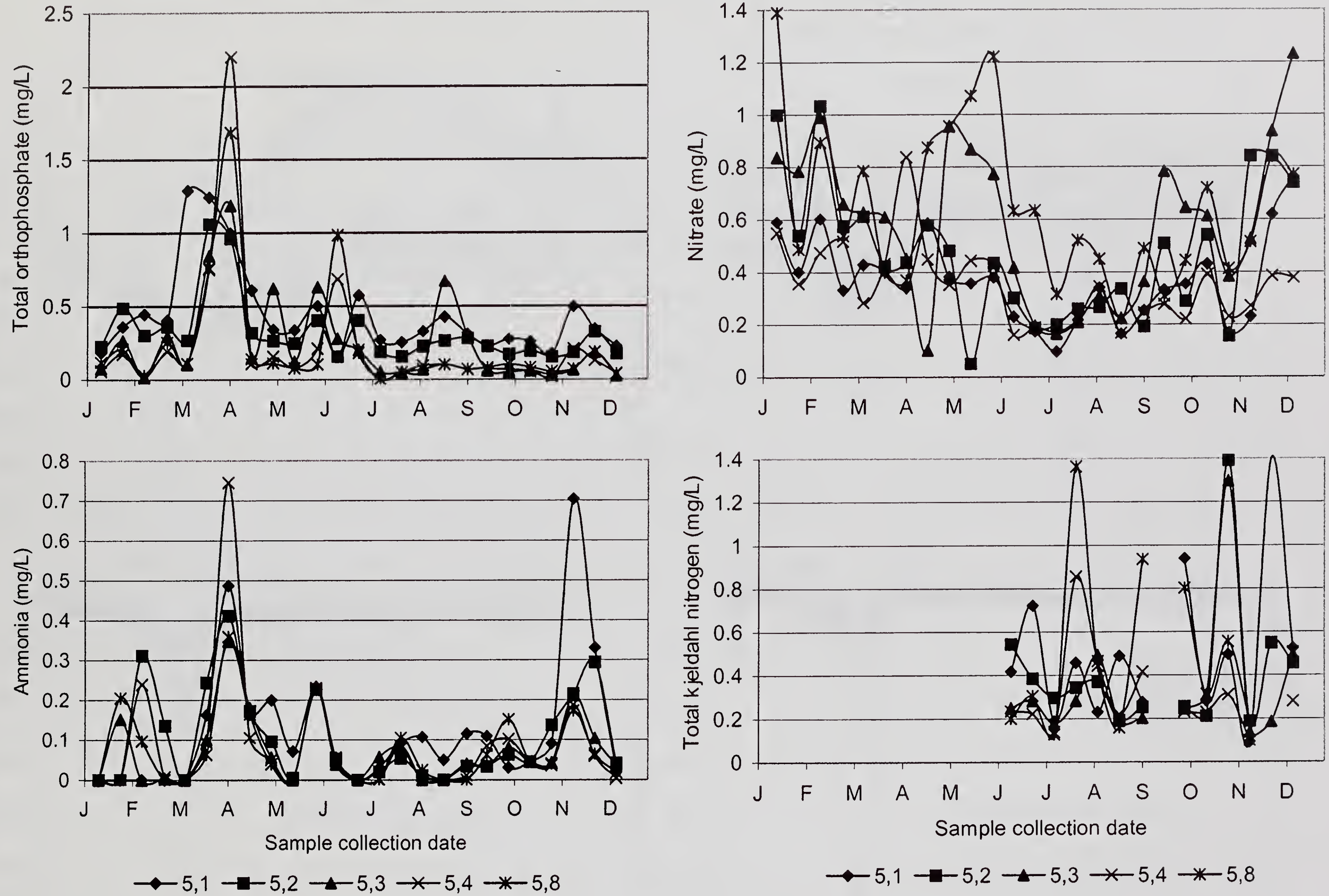
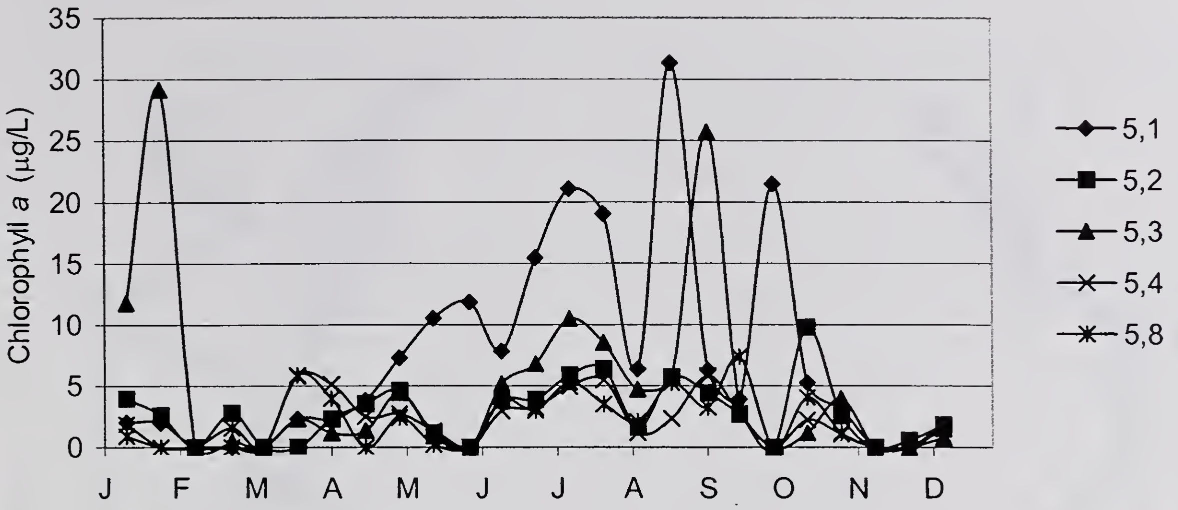
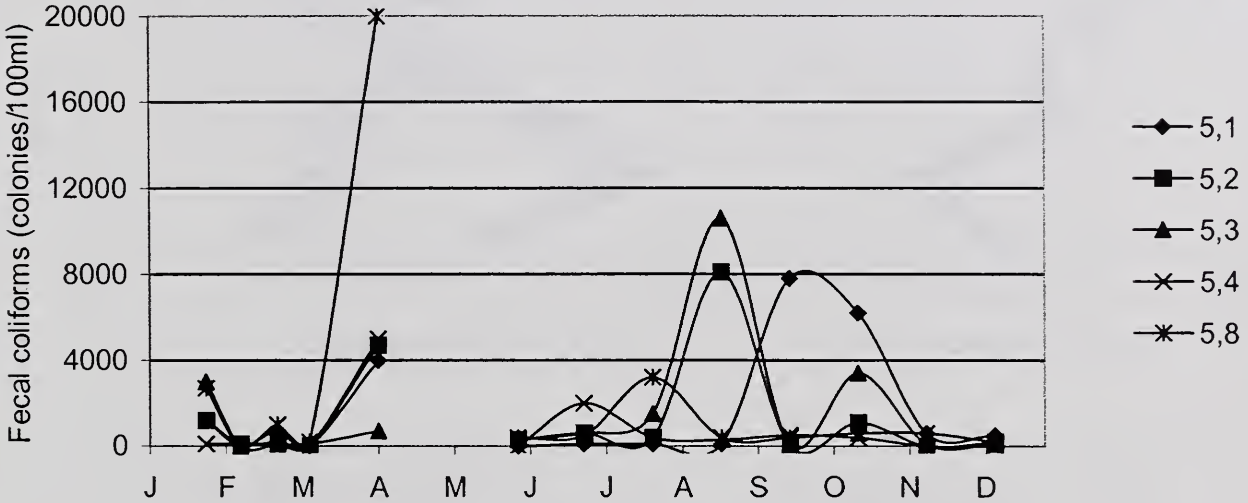


Fig. 5-5. 2000 chlorophyll *a*, fecal coliform, and enterococci measurements for Hickahala Creek.





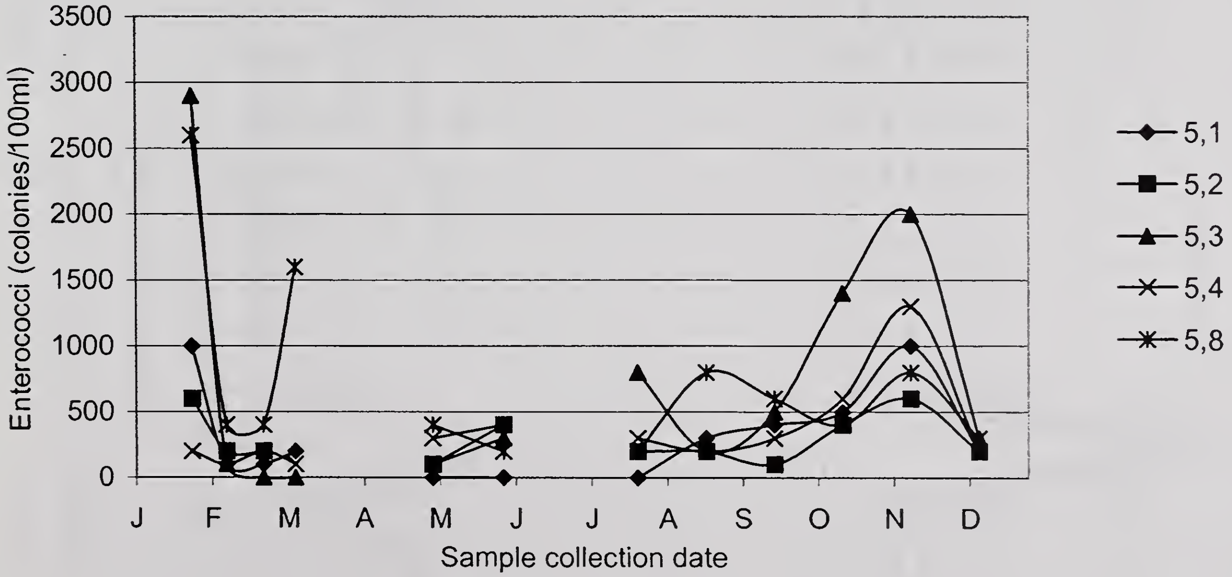


Fig. 6-1. 2000 depth to water, water depth, temperature, and dissolved oxygen measurements for Black Creek.

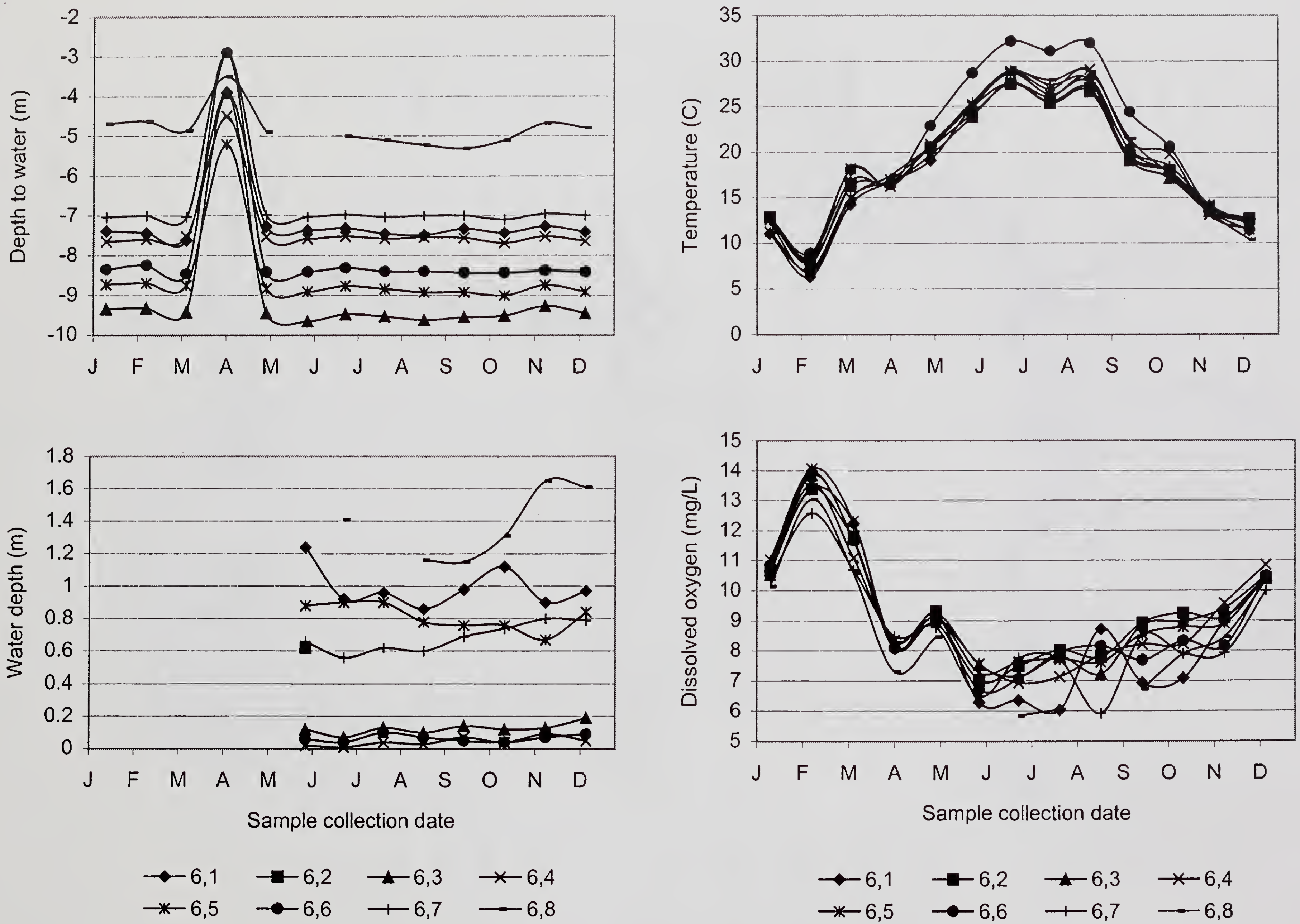


Fig. 6-2. 2000 conductivity, salinity, pH, and turbidity measurements for Black Creek.

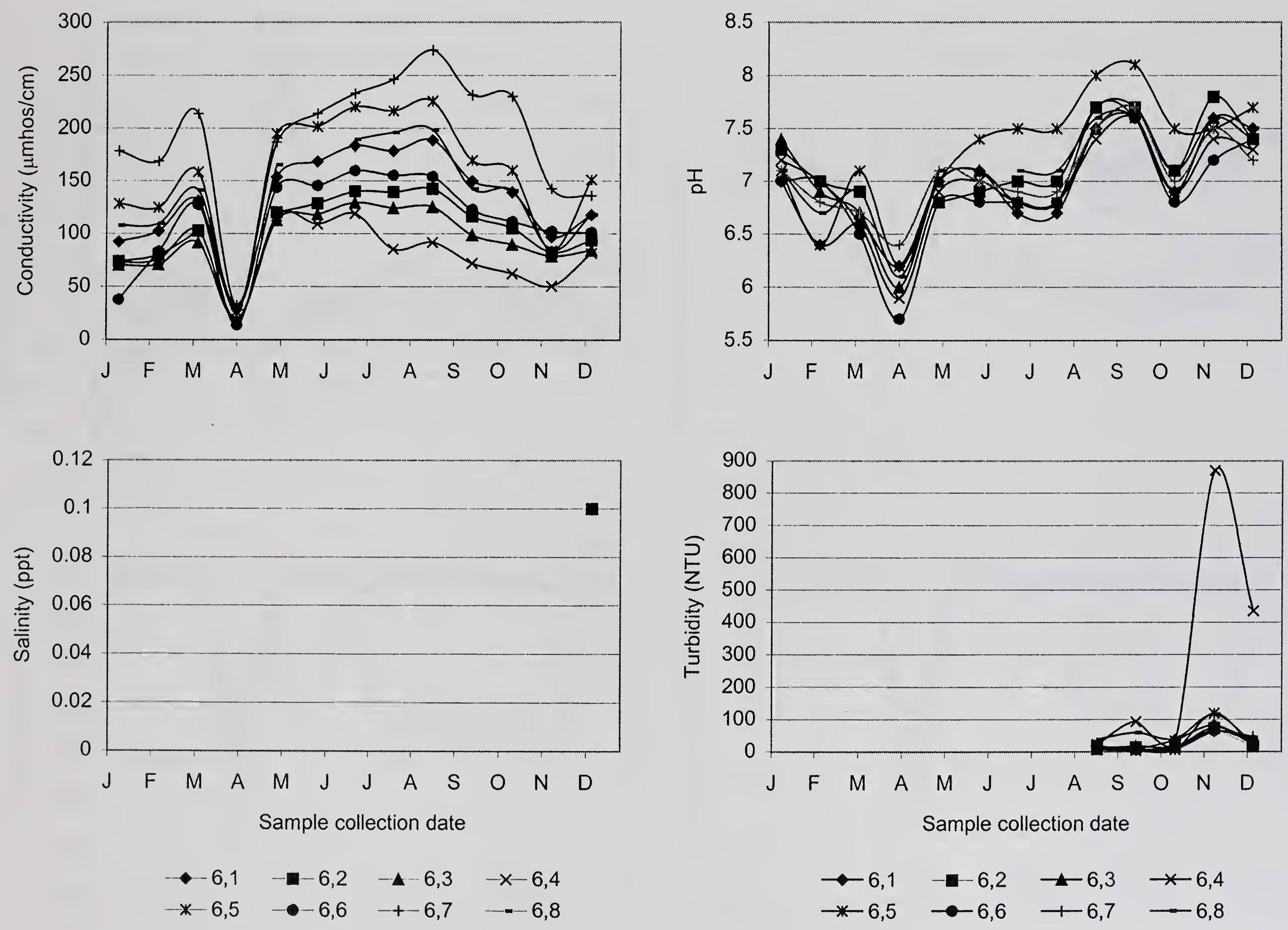


Fig. 6-3. 2000 total, dissolved and suspended solids, and filtered orthophosphate concentrations for Black Creek.

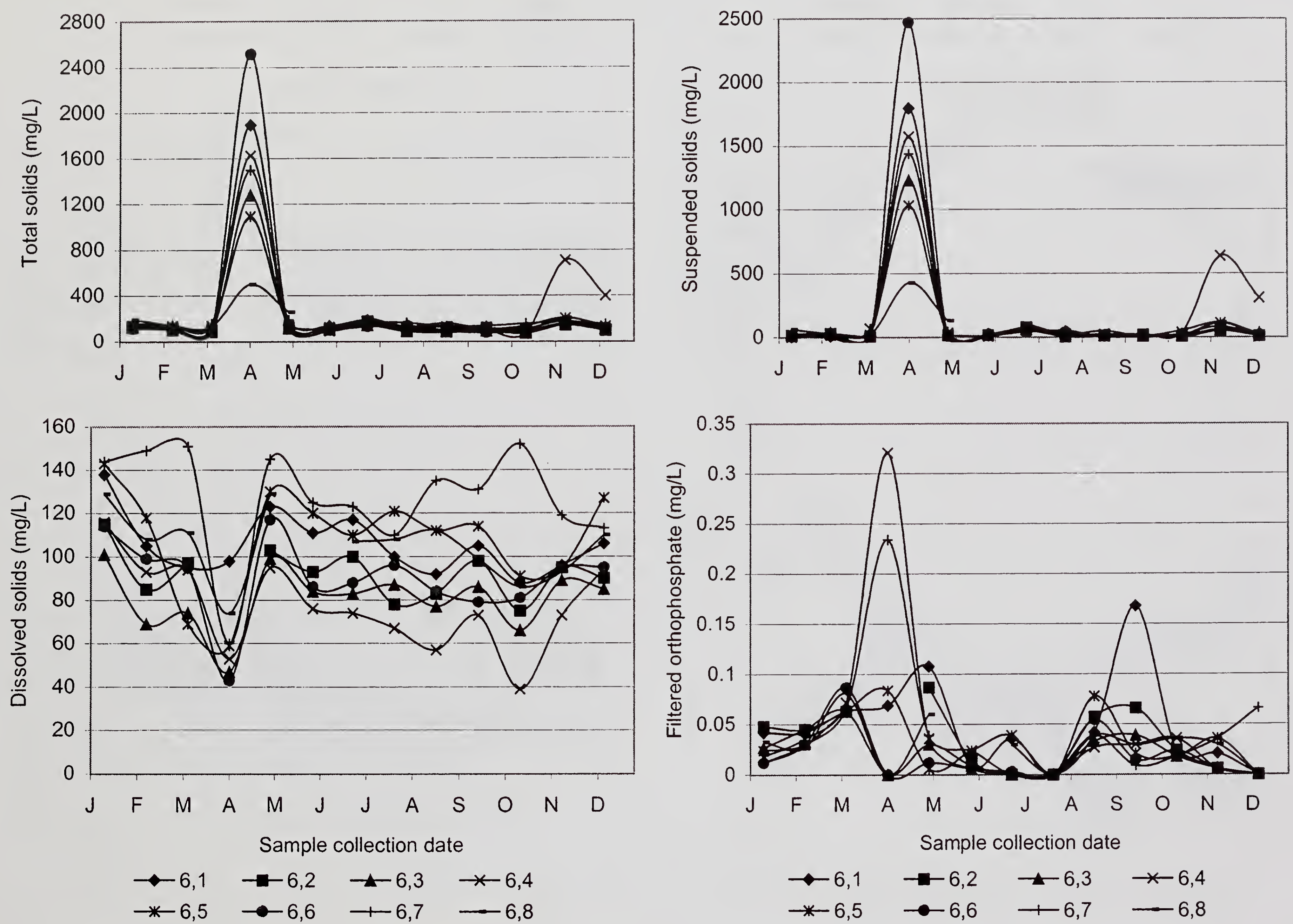


Fig. 6-4. 2000 total orthophosphate, ammonia, nitrate, and total kjeldahl nitrogen concentrations for Black Creek.

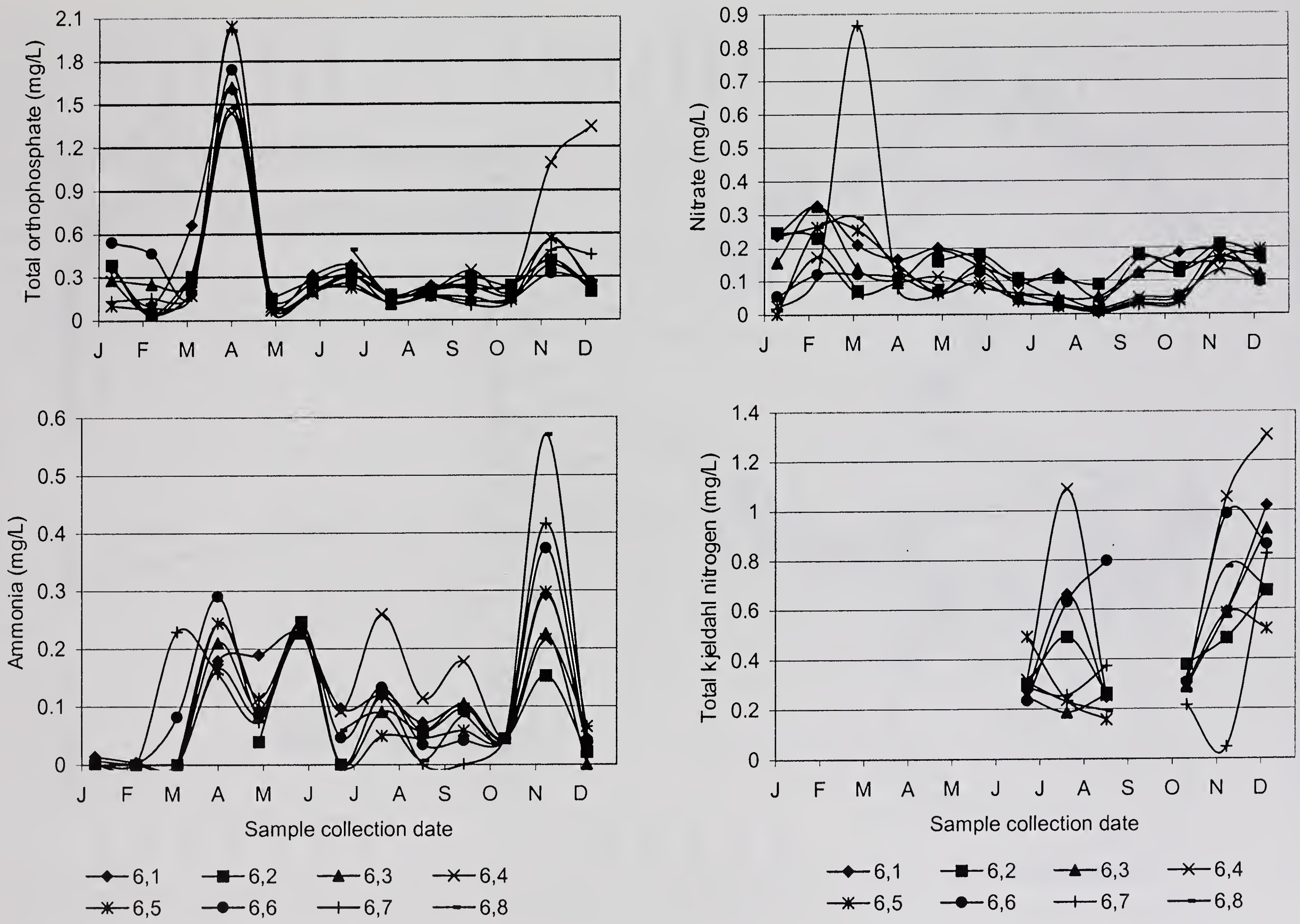


Fig. 6-5. 2000 chlorophyll *a*, fecal coliform, and enterococci measurements for Black Creek.

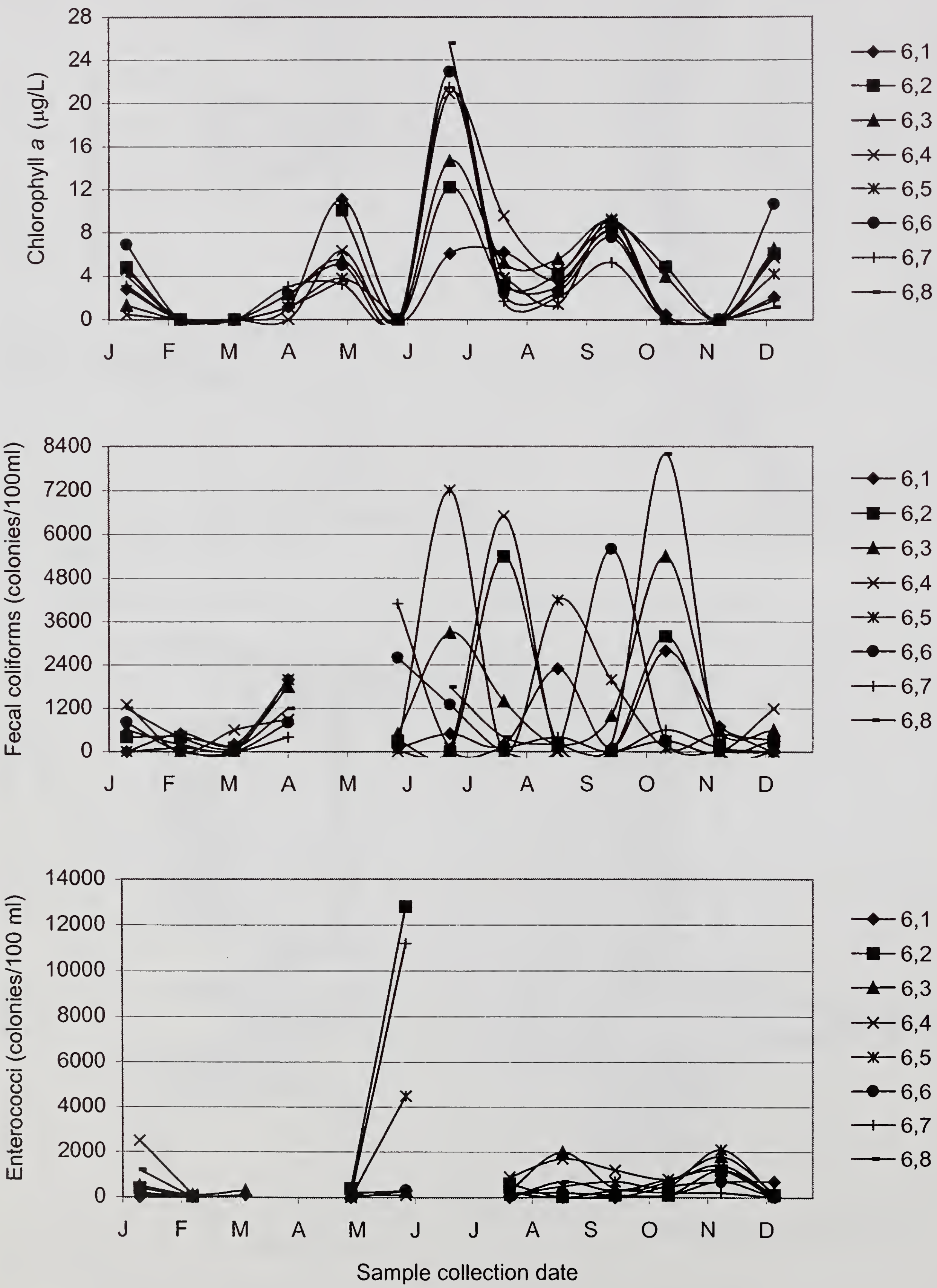


Fig. 7-1. 2000 depth to water, water depth, temperature, and dissolved oxygen measurements for Coldwater River and Pigeon Roost Creek.

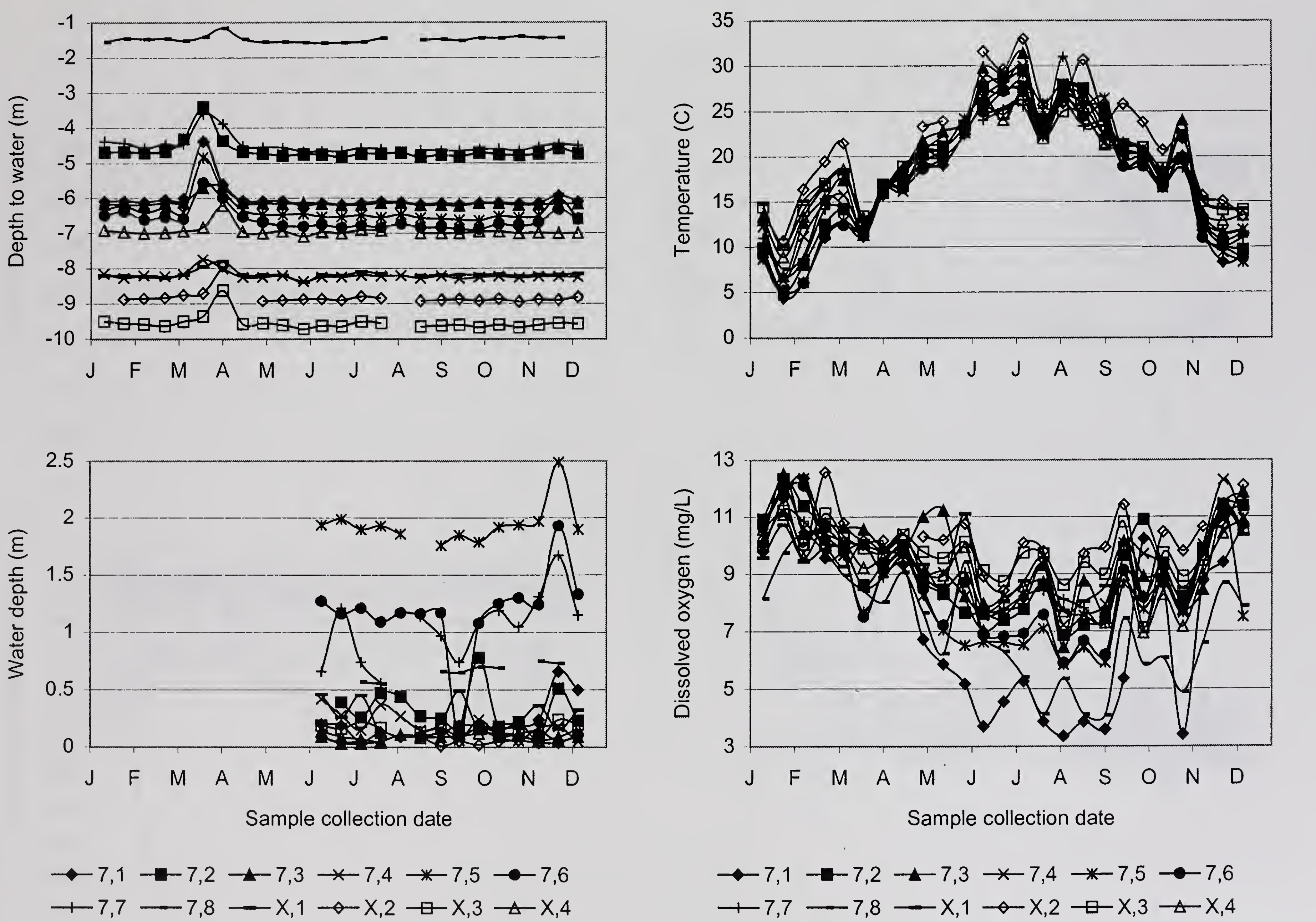


Fig. 7-2. 2000 conductivity, salinity, pH, and turbidity measurements for Coldwater River and Pigeon Roost Creek.

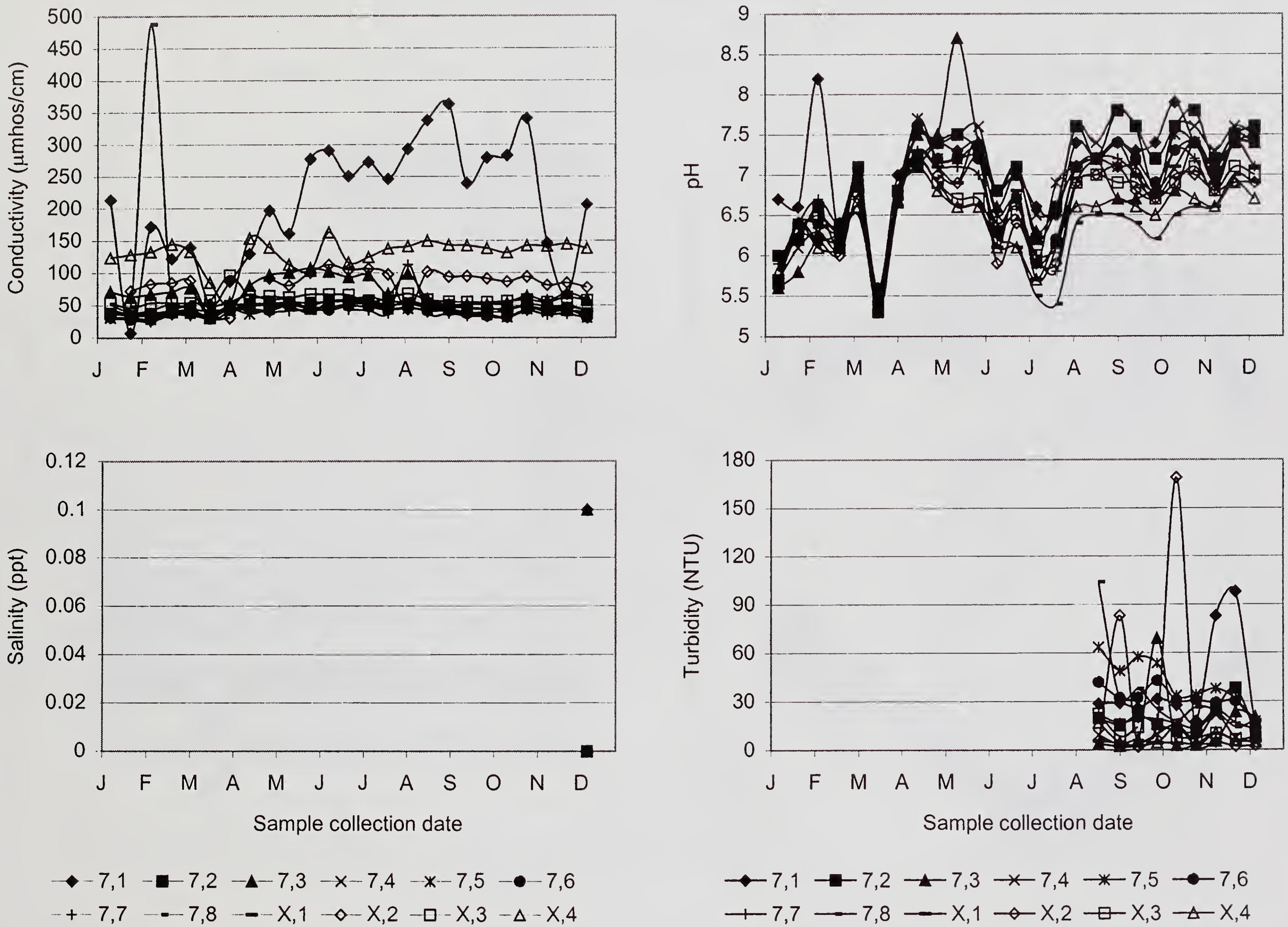


Fig. 7-3. 2000 total, dissolved and suspended solids, and filtered orthophosphate concentrations for Coldwater River and Pigeon Roost Creek.

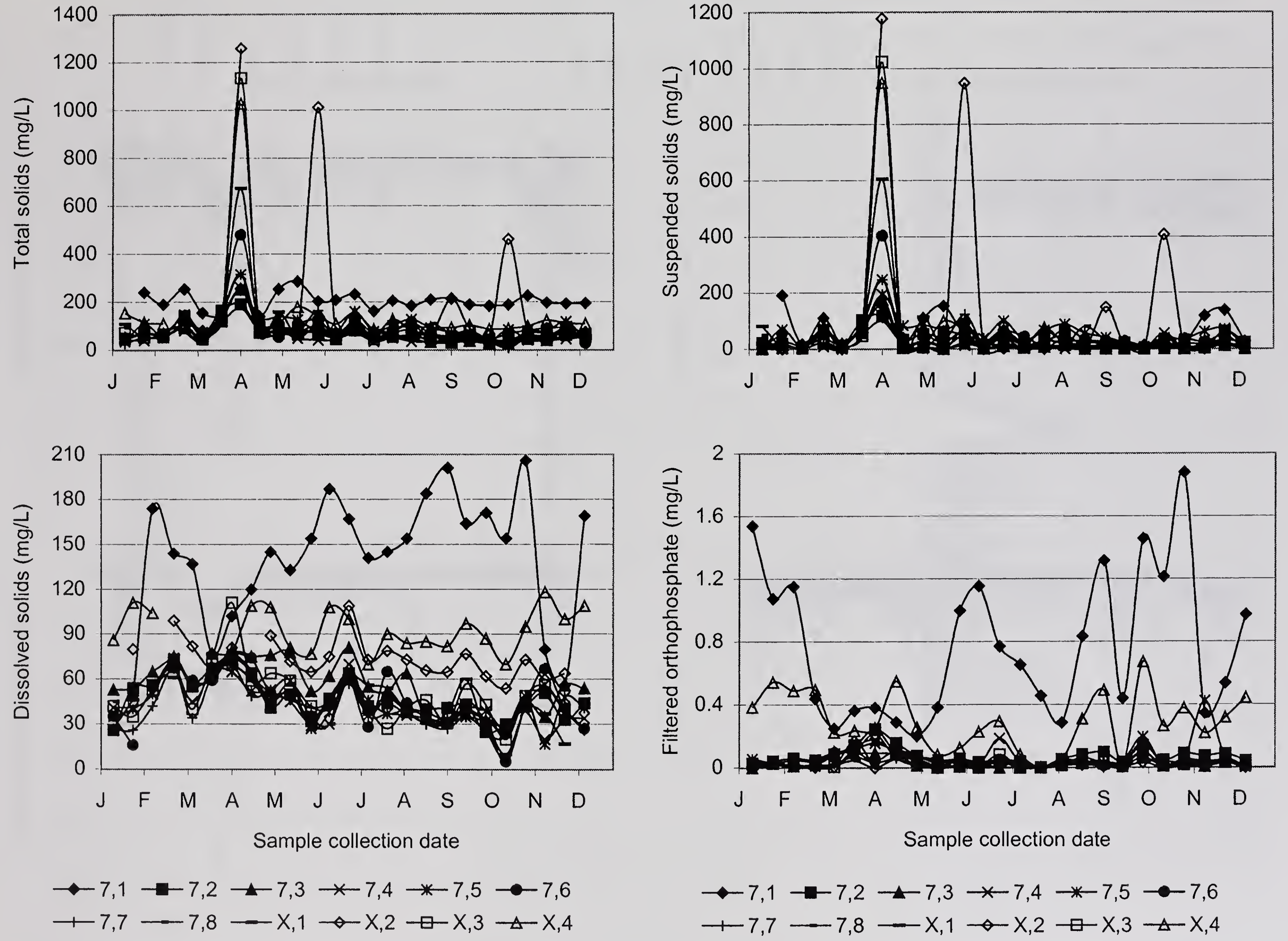


Fig. 7-4. 2000 total orthophosphate, ammonia, nitrate, and total kjeldahl nitrogen concentrations for Coldwater River and Pigeon Roost Creek.

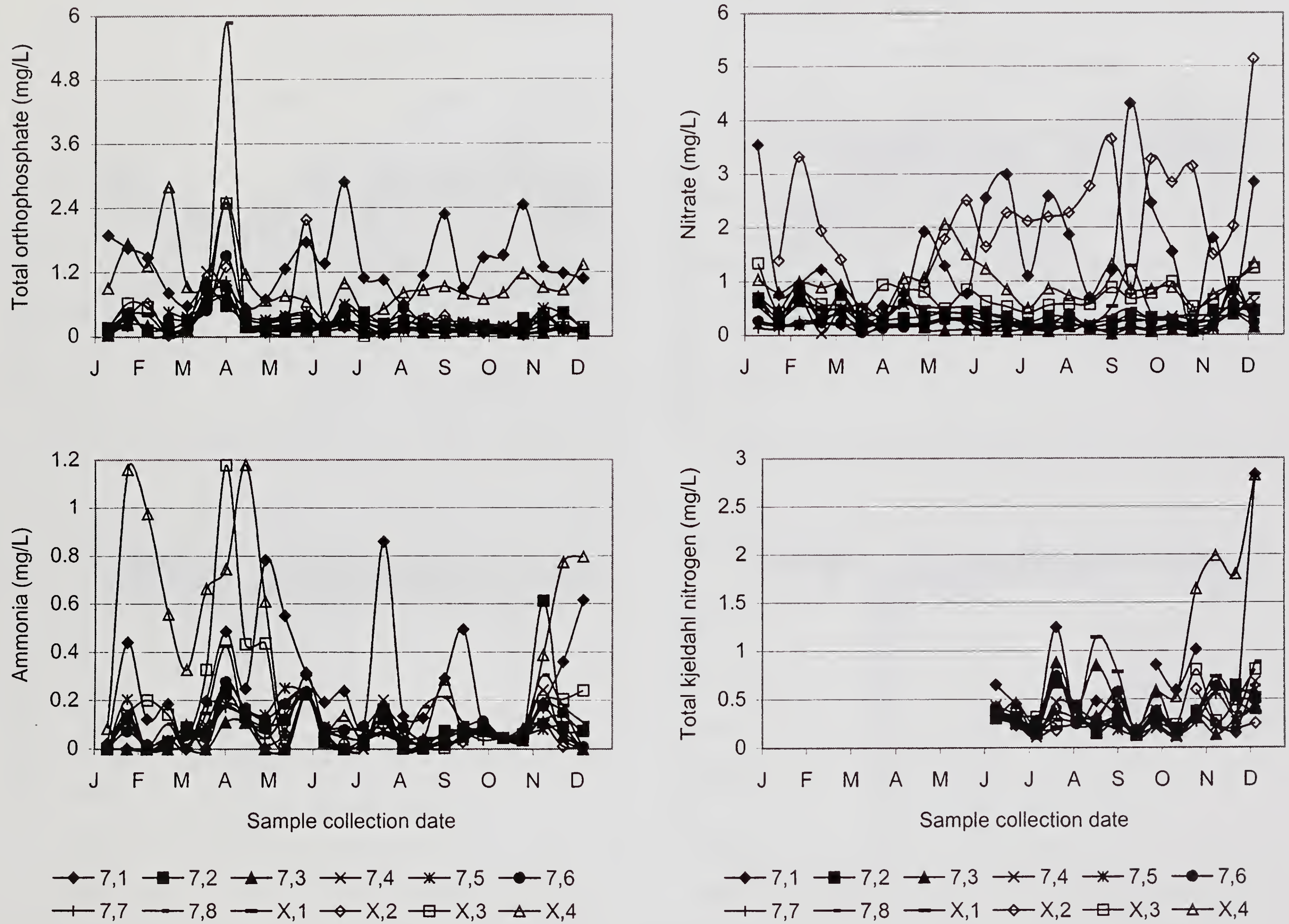


Fig. 7-5. 2000 chlorophyll *a*, fecal coliform, and enterococci measurements for Coldwater River and Pigeon Roost Creek.

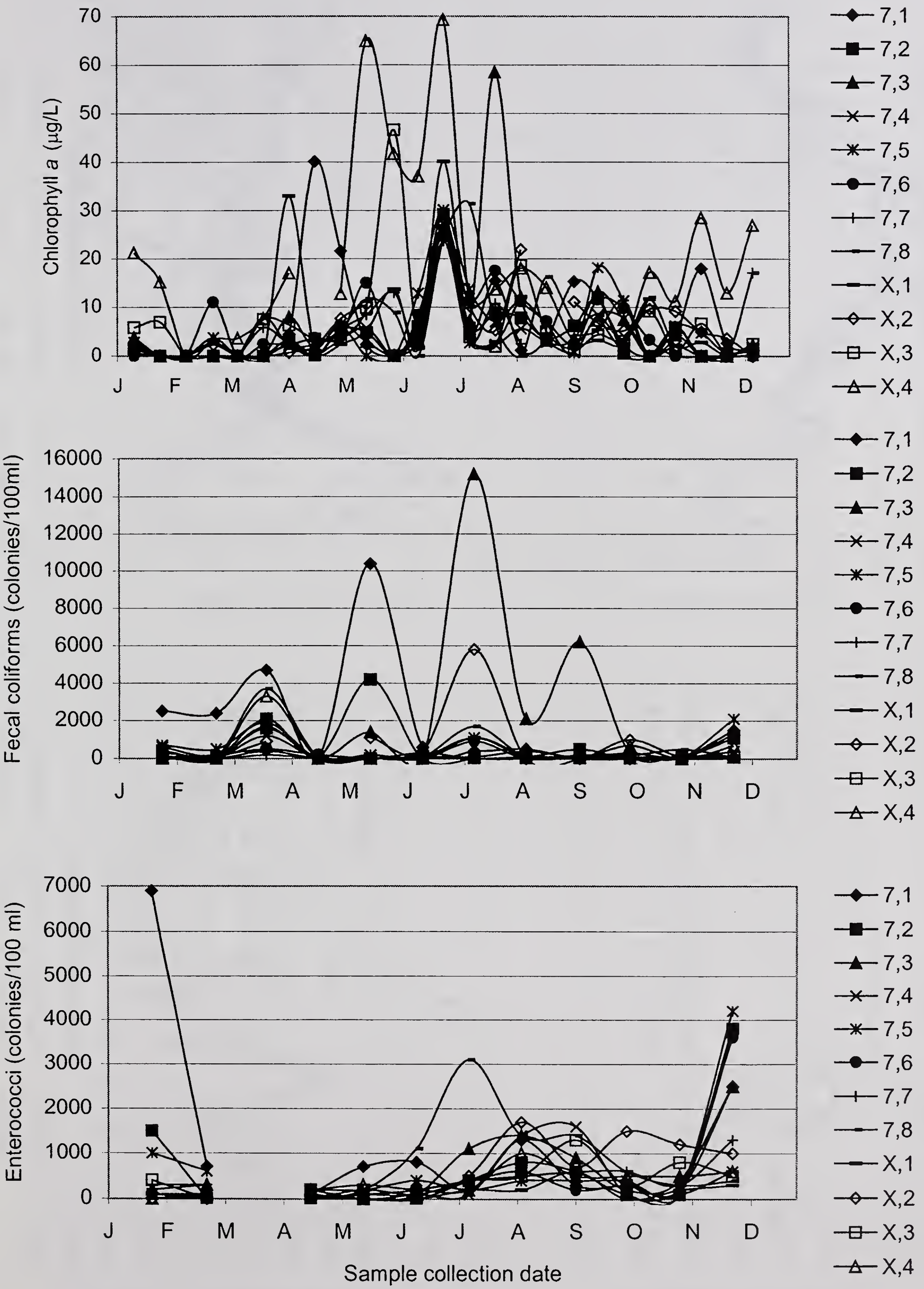


Fig. 8-1. 2000 depth to water, water depth, temperature, and dissolved oxygen measurements for Abiaca Creek.

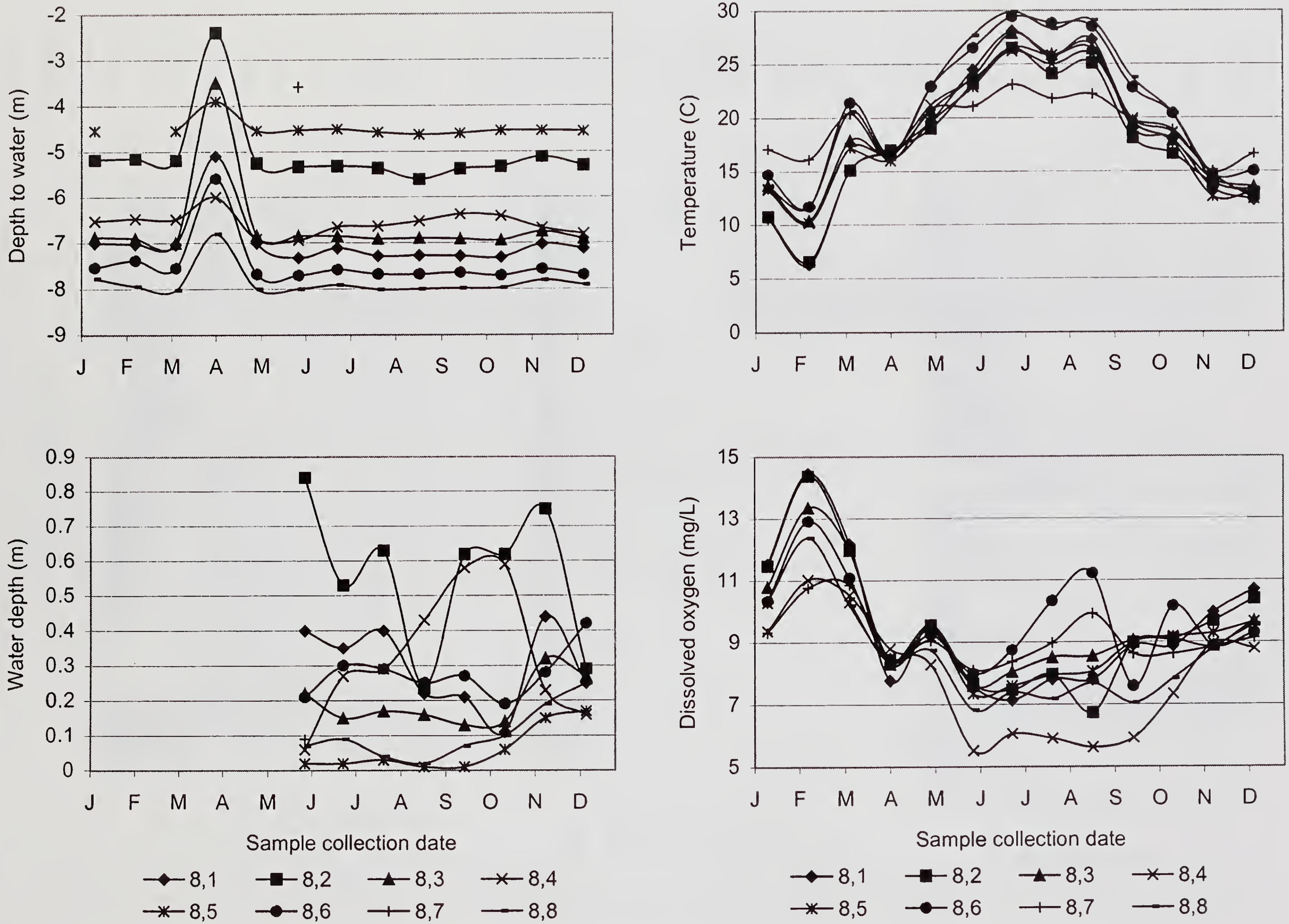


Fig. 8-2. 2000 conductivity, salinity, pH, and turbidity measurements for Abiaca Creek.

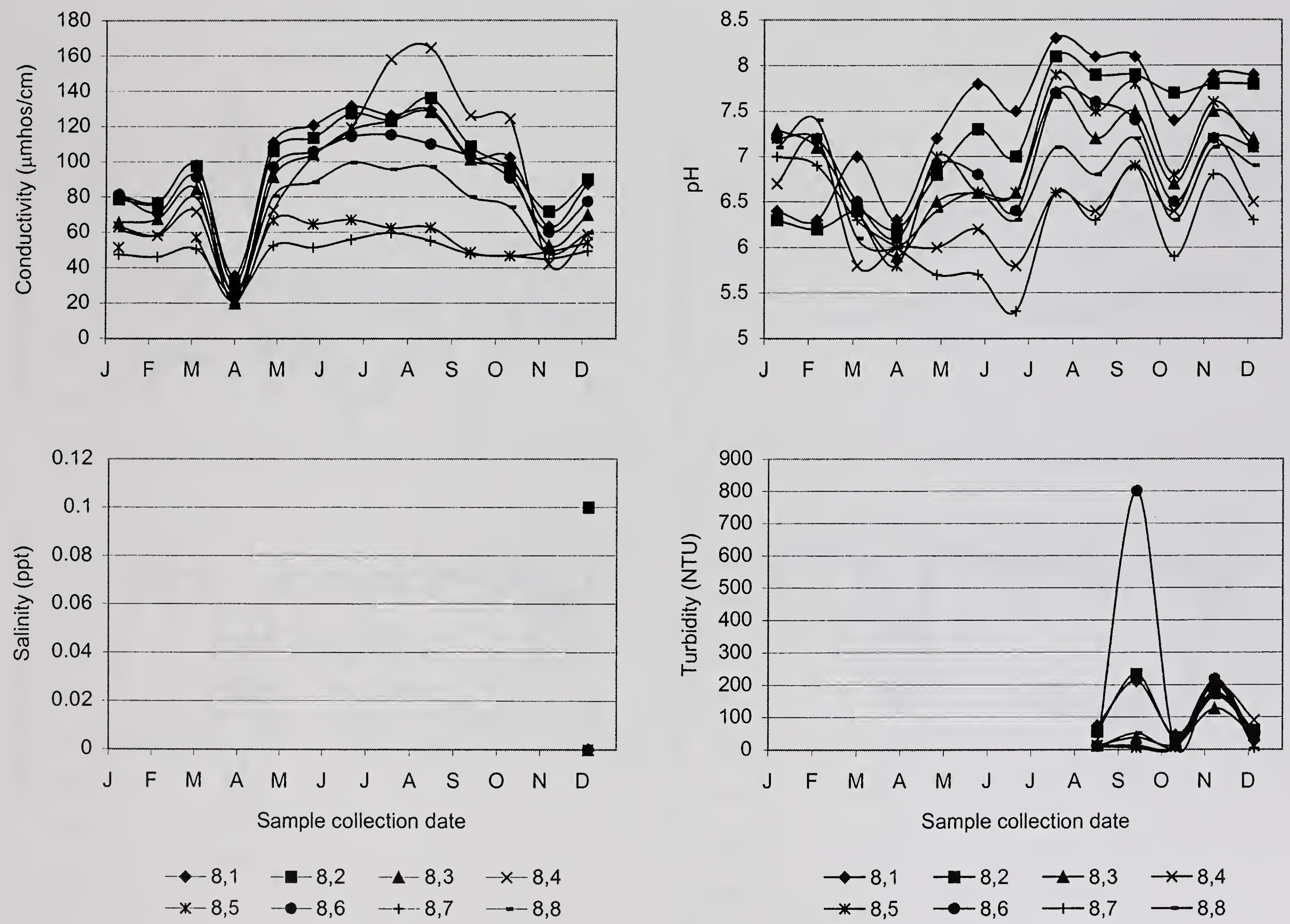


Fig. 8-3. 2000 total, dissolved and suspended solids, and filtered orthophosphate measurements for Abiaca Creek.

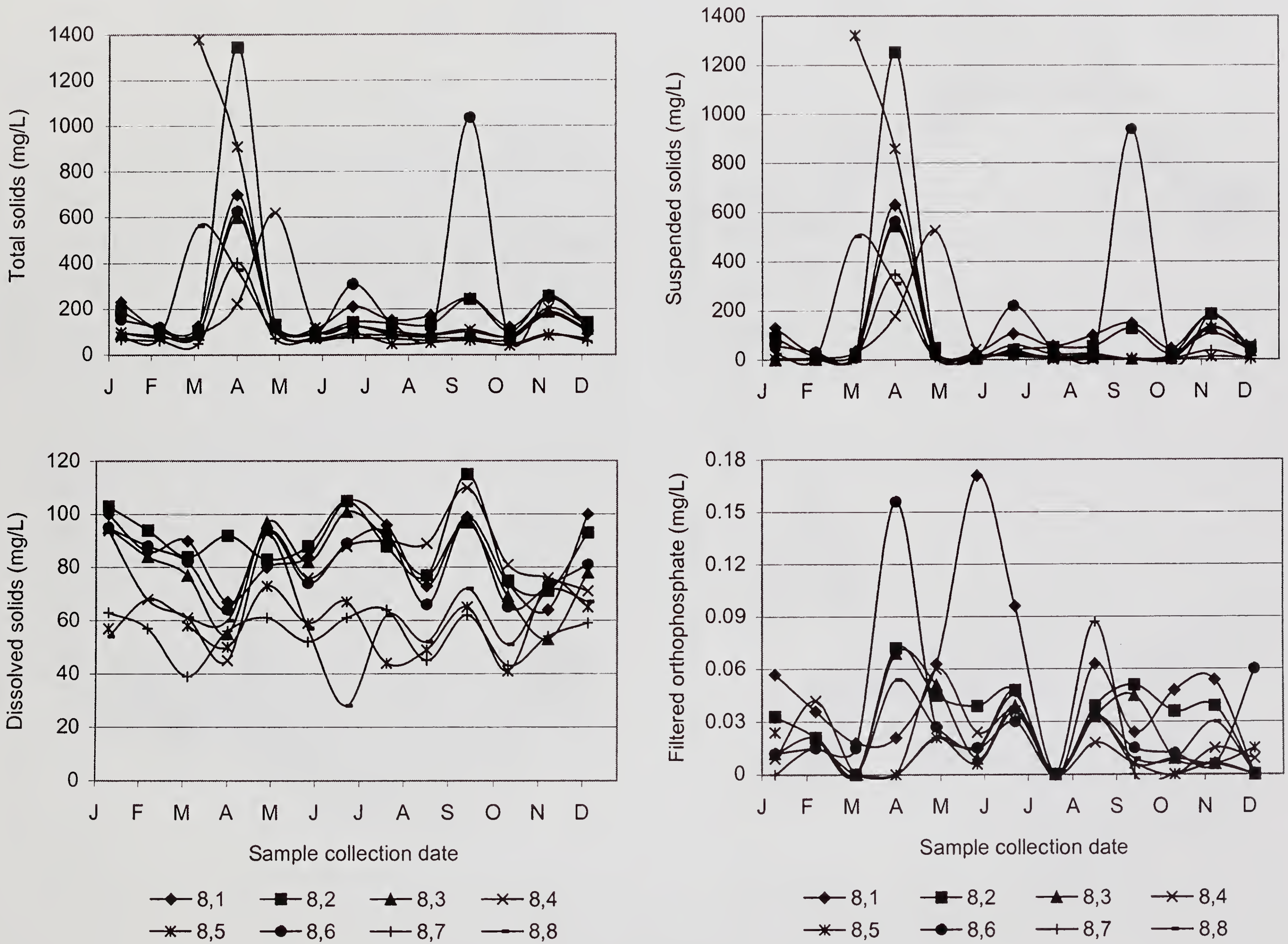


Fig. 8-4. 2000 total orthophosphate, ammonia, nitrate, and total kjeldahl nitrogen concentrations for Abiaca Creek.

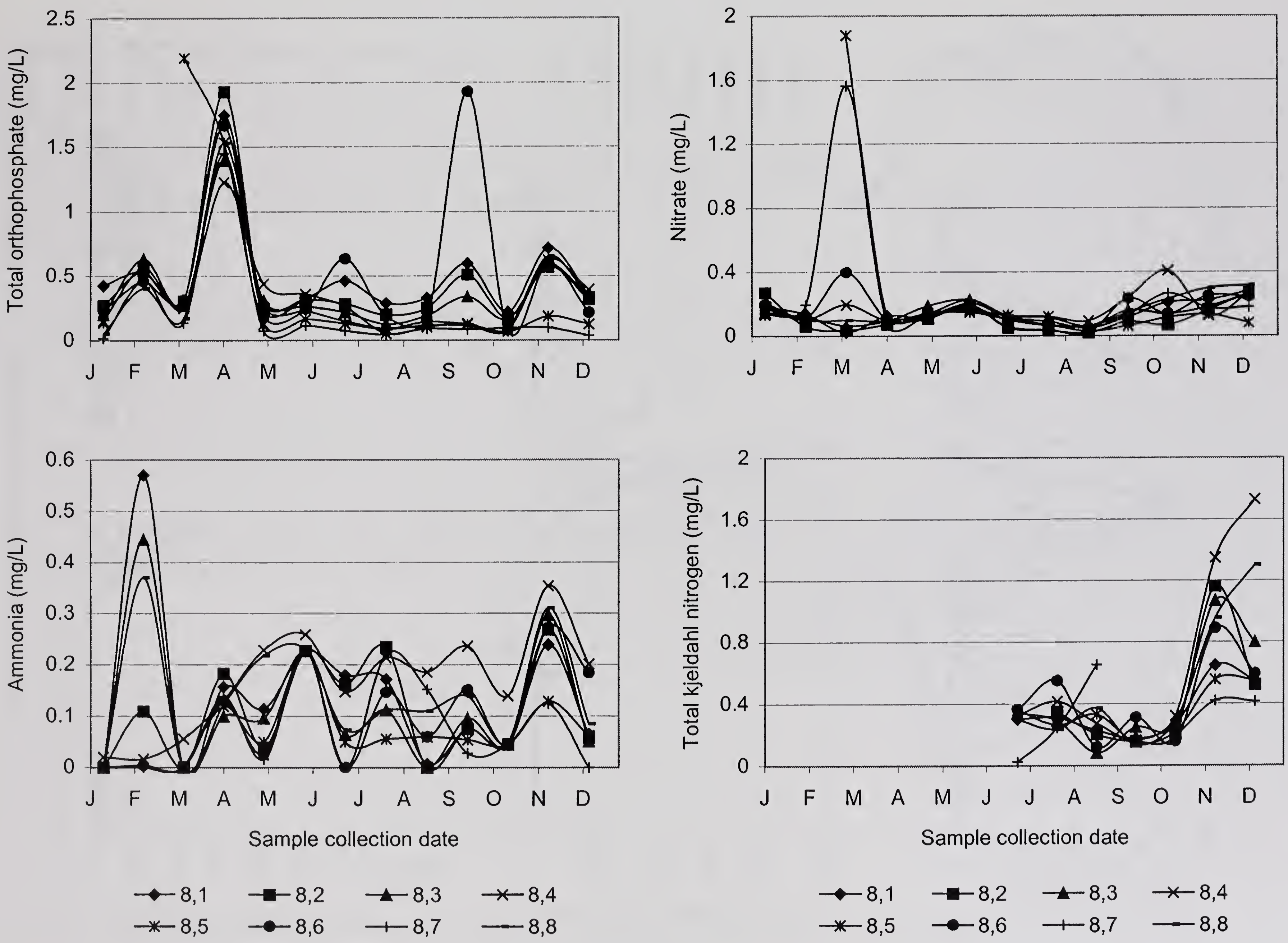
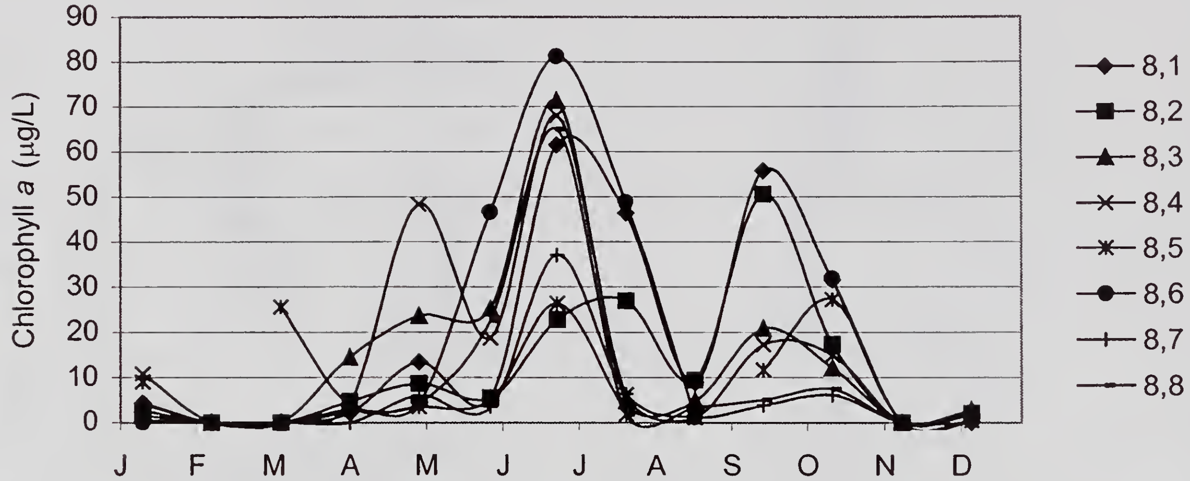
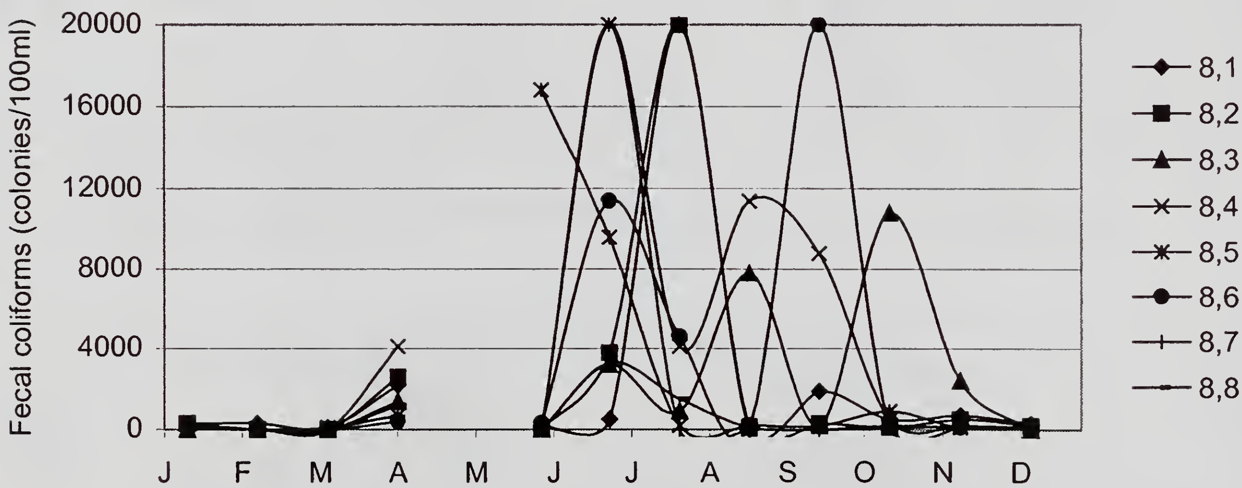


Fig. 8-5. 2000 chlorophyll *a*, fecal coliform, and enterococci measurements for Abiaca Creek.





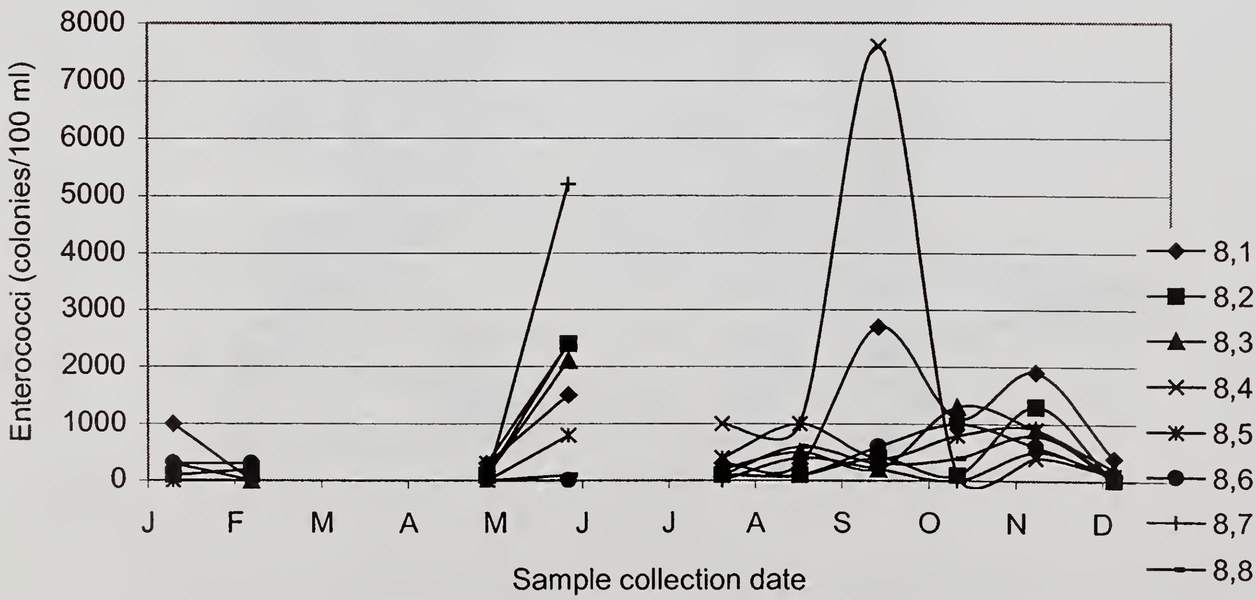


Fig. 9-1. 2000 depth to water, water depth, temperature, and dissolved oxygen measurements for Toby Tubby Creek.

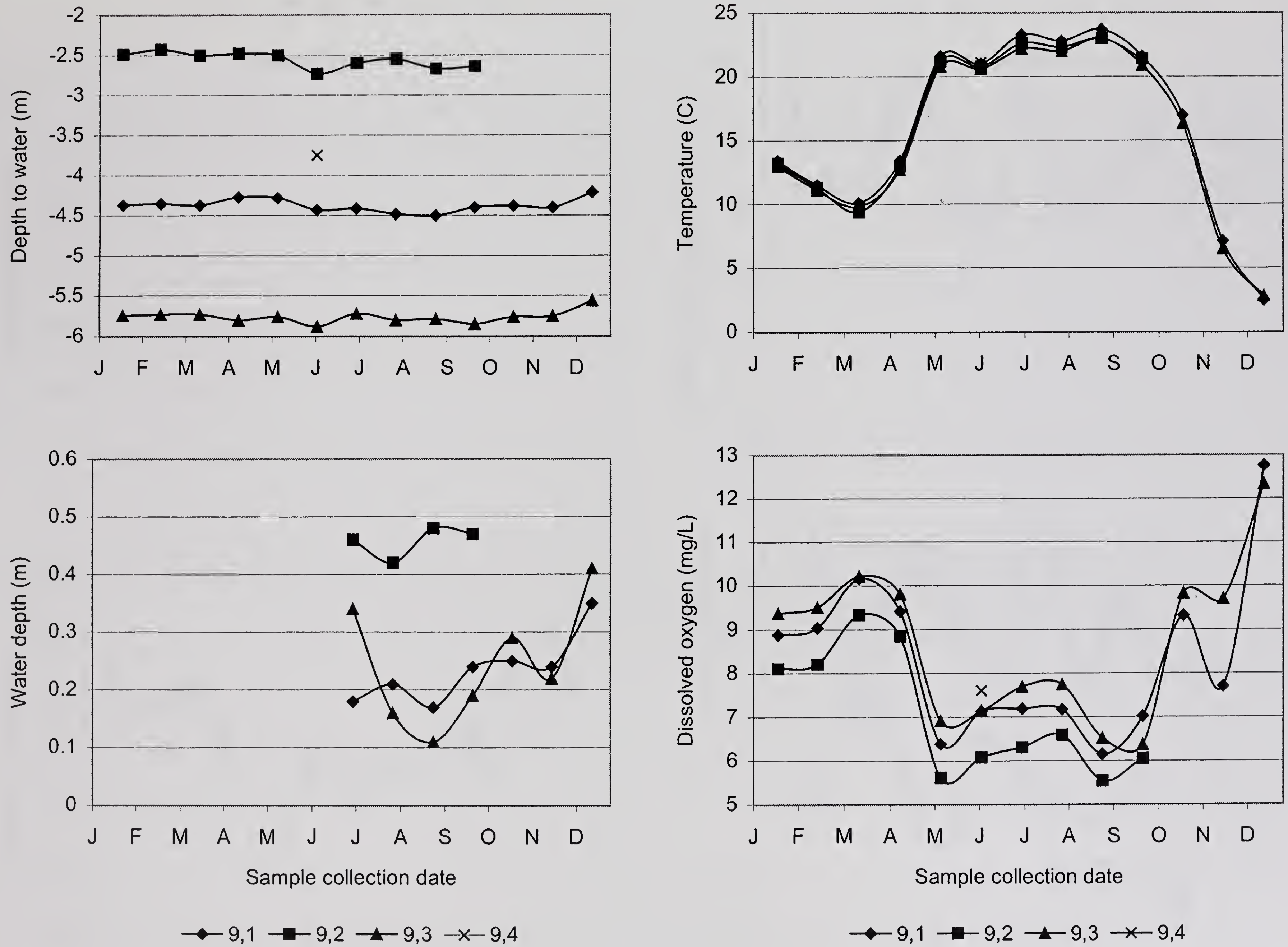


Fig. 9-2. 2000 conductivity, salinity, pH, and hardness measurements for Toby Tubby Creek.

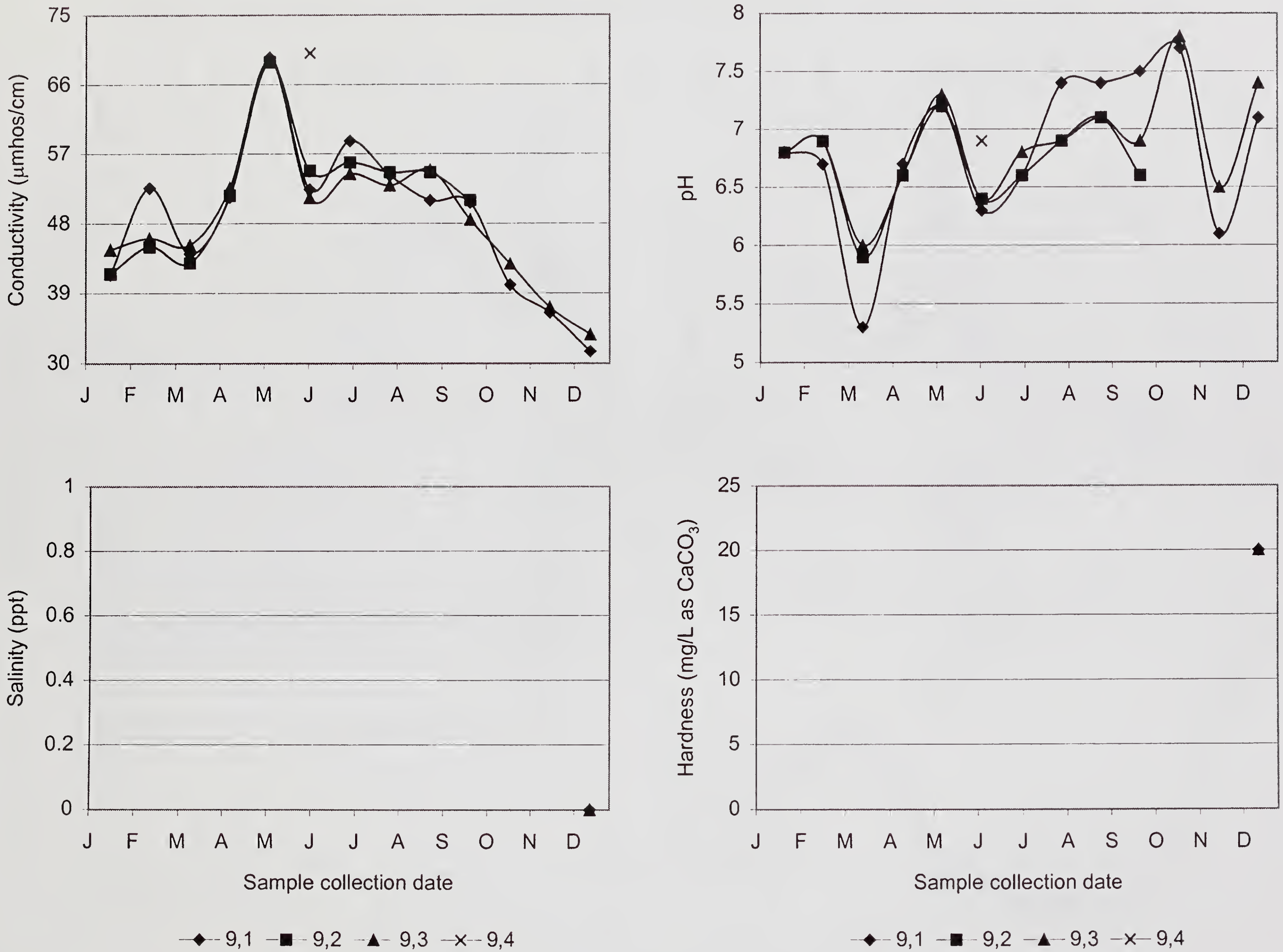


Fig. 9-3. 2000 alkalinity, turbidity, and total and dissolved solids measurements for Toby Tubby Creek.

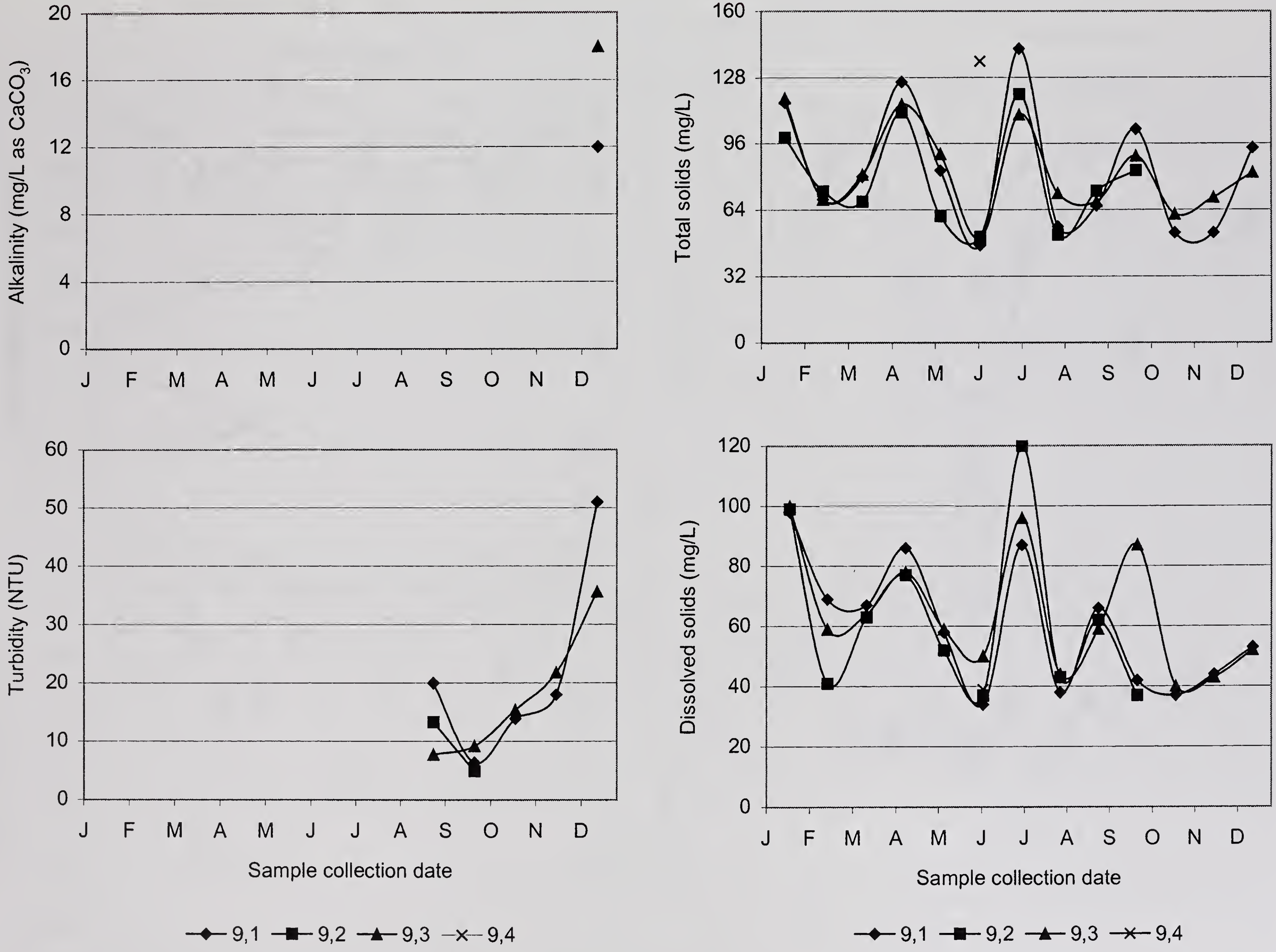


Fig. 9-4. 2000 suspended solids, filtered orthophosphate, total orthophosphate, and ammonia concentrations for Toby Tubby Creek.

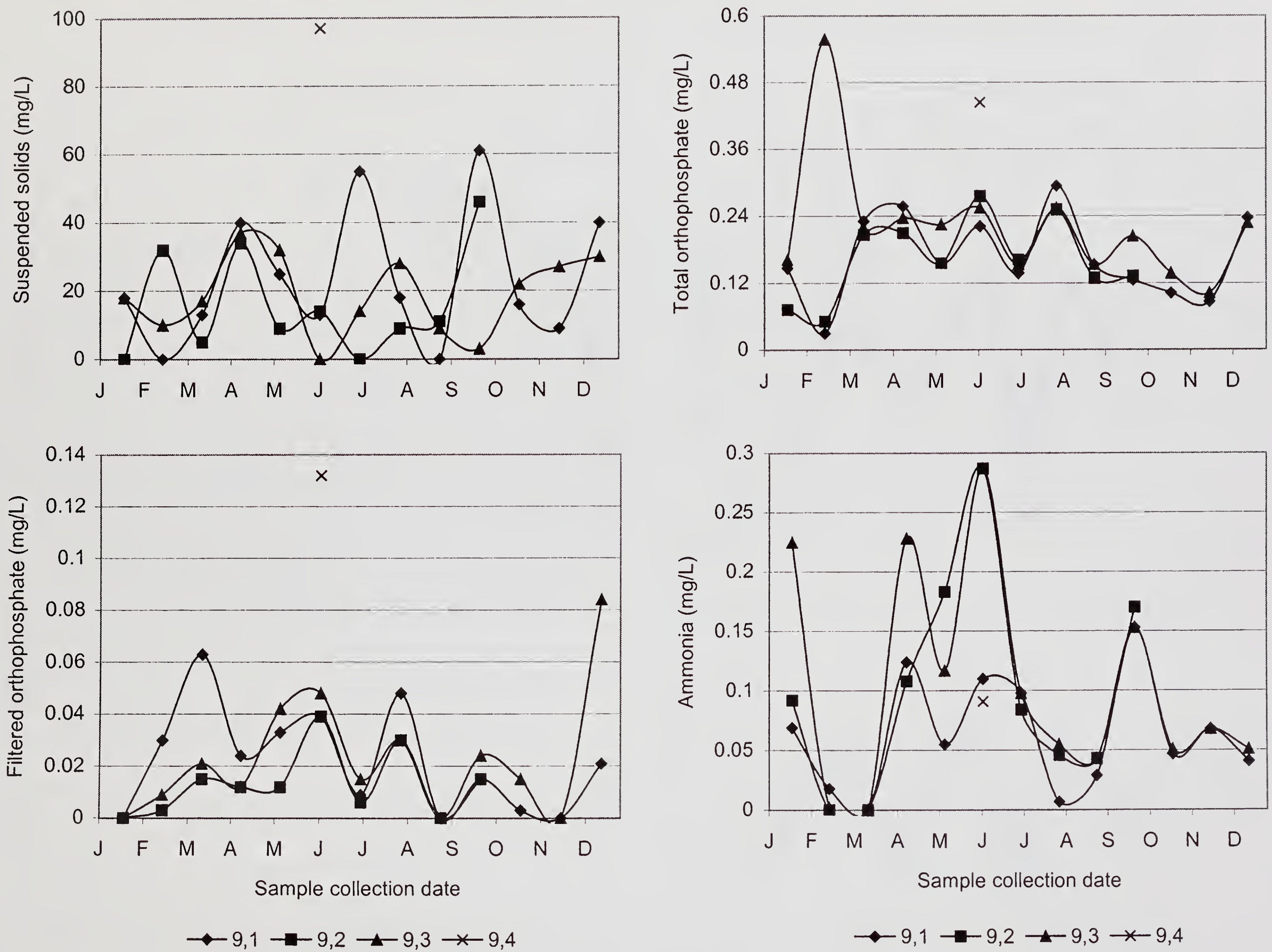


Fig. 9-5. 2000 nitrate, total kjeldahl nitrogen, and chlorophyll *a* concentrations for Toby Tubby Creek.

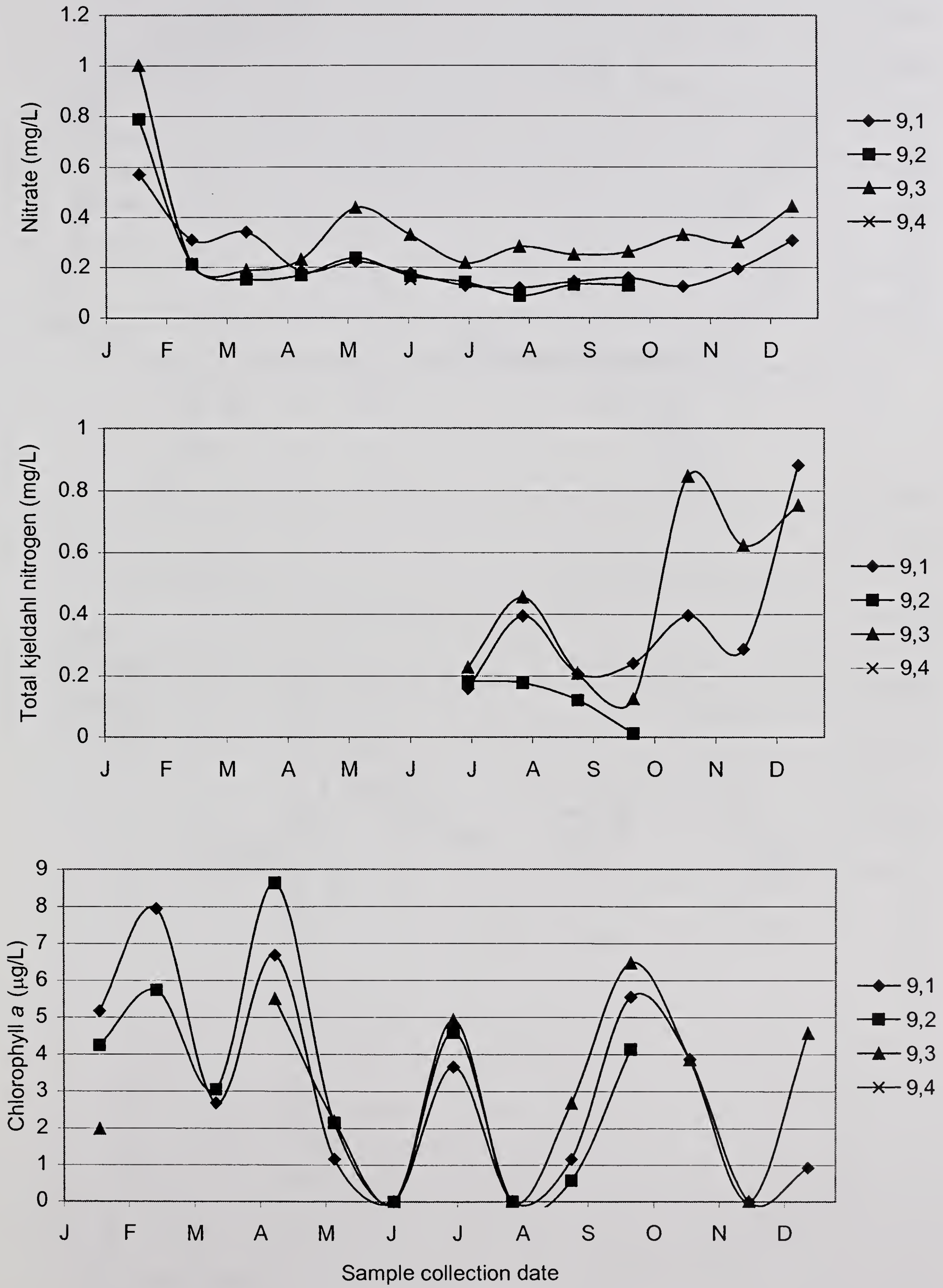


Fig. 9-6. 2000 fecal coliform and enterococci measurements for Toby Tubby Creek.

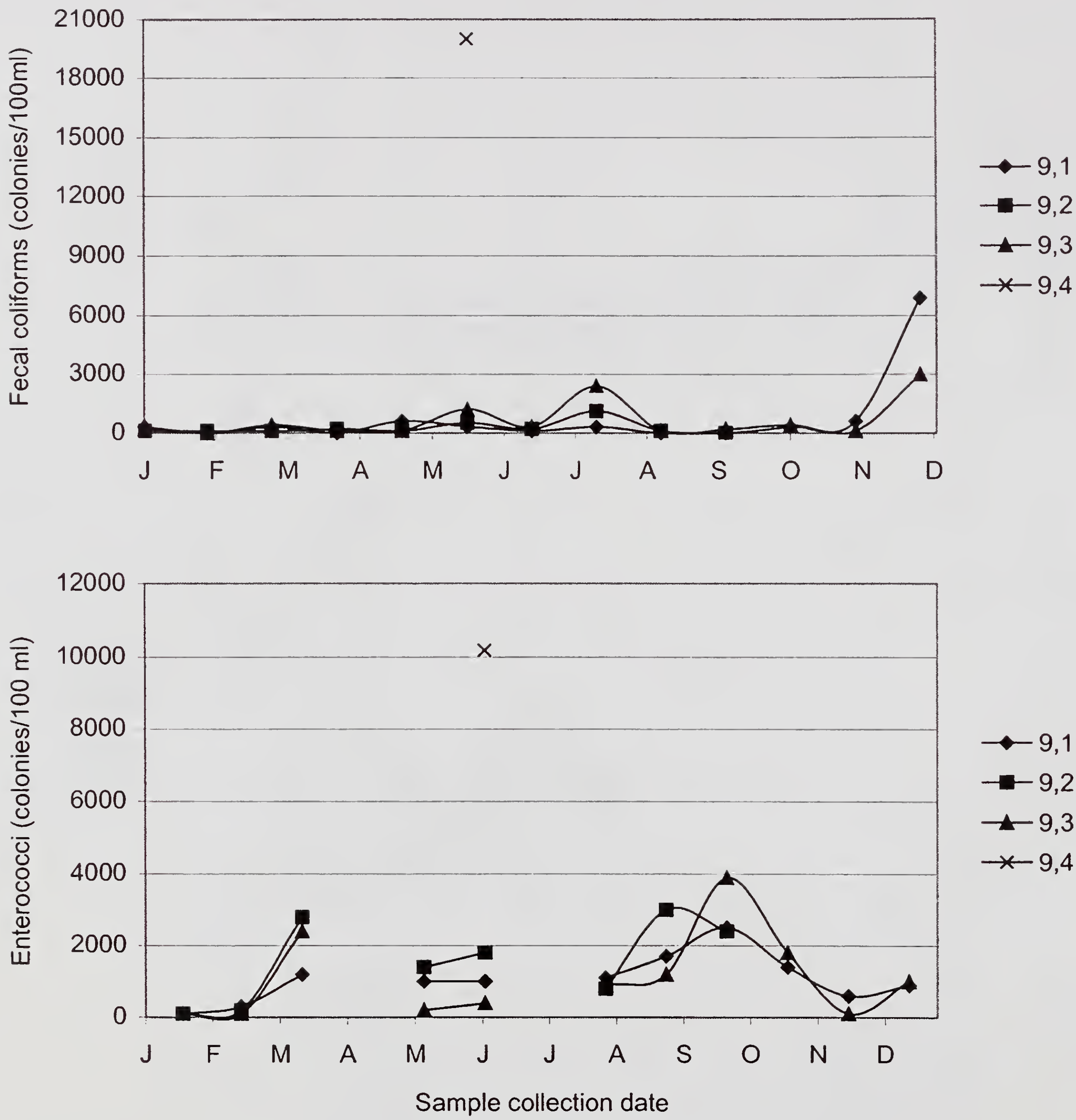


Fig. 13-1. 2000 depth to water, water depth, temperature, and dissolved oxygen measurements for Burney Branch Creek.

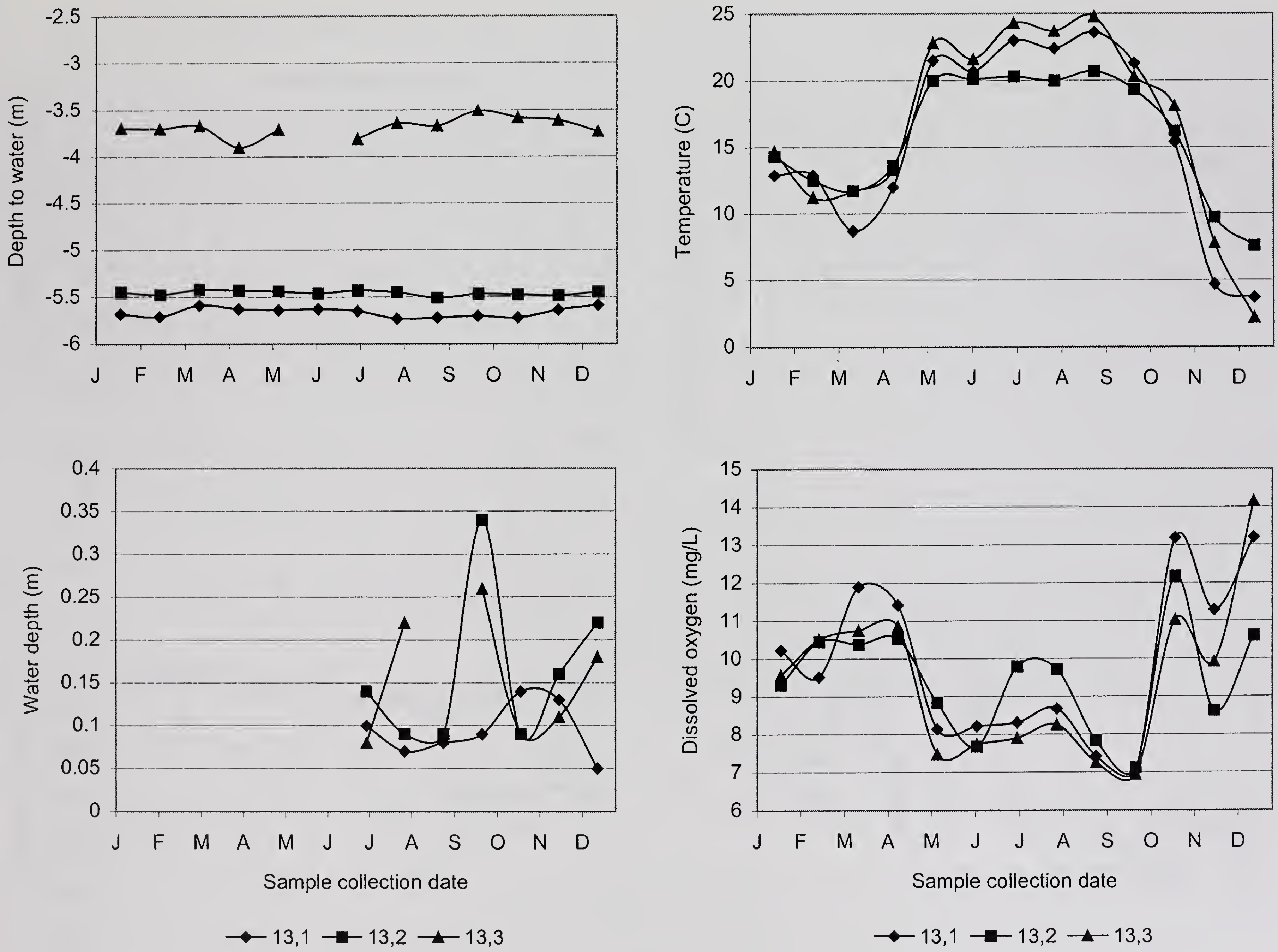


Fig. 13-2. 2000 conductivity, salinity, pH, and hardness measurements for Burney Branch Creek.

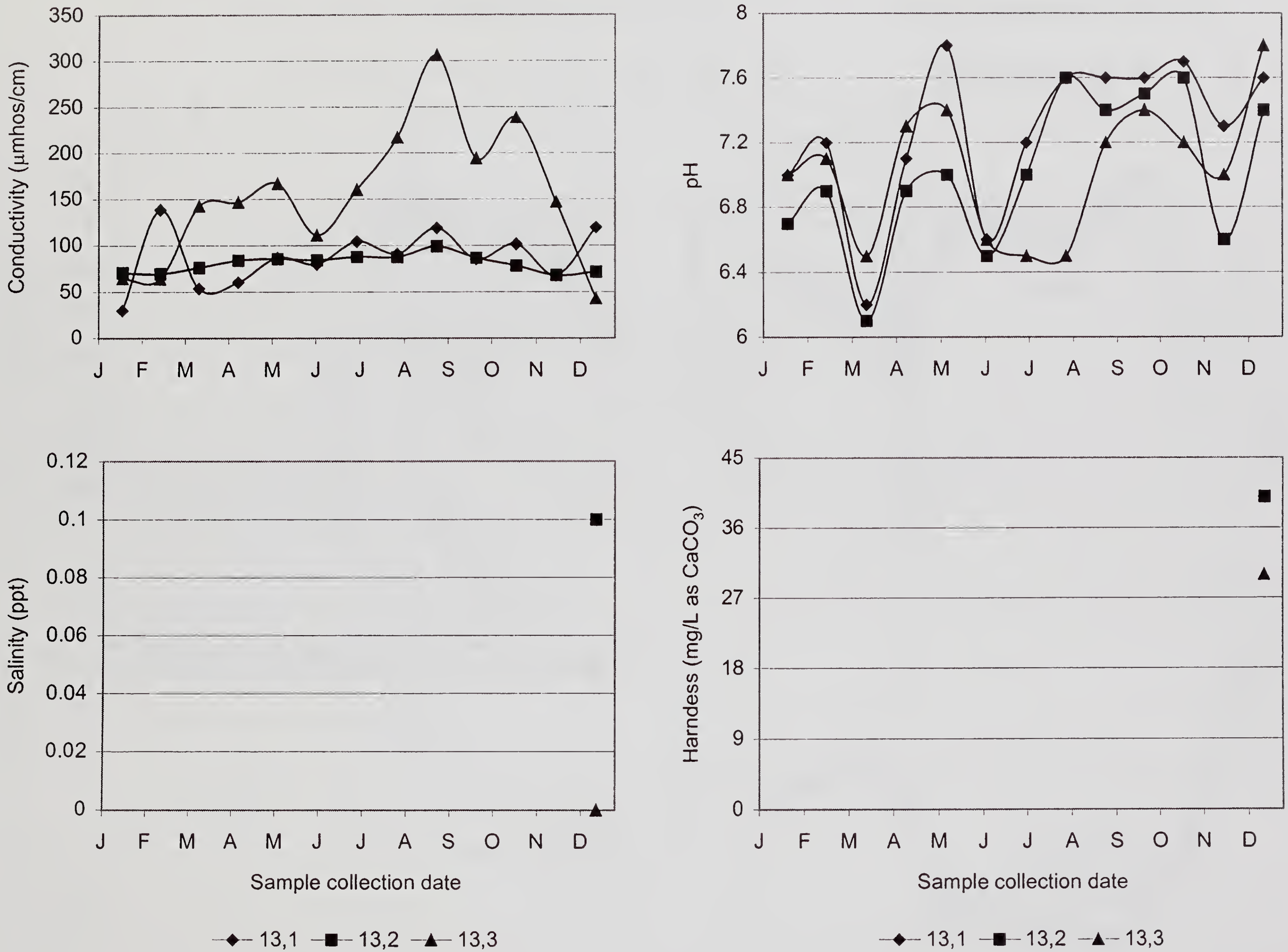


Fig. 13-3. 2000 alkalinity, turbidity, and total and dissolved solids measurements for Burney Branch Creek.

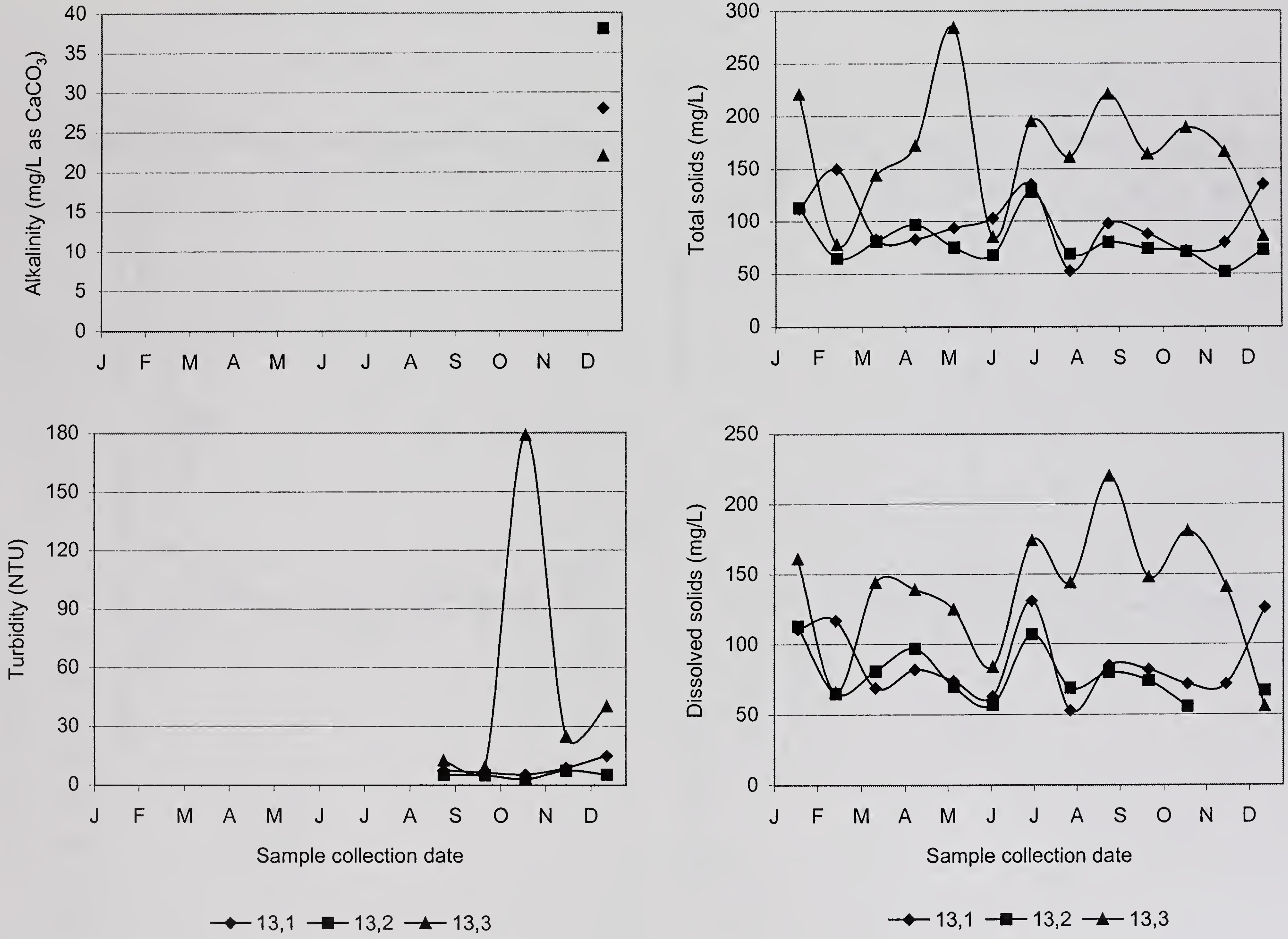


Fig. 13-4. 2000 suspended solids, filtered orthophosphate, total orthophosphate, and ammonia concentrations for Burney Branch Creek.

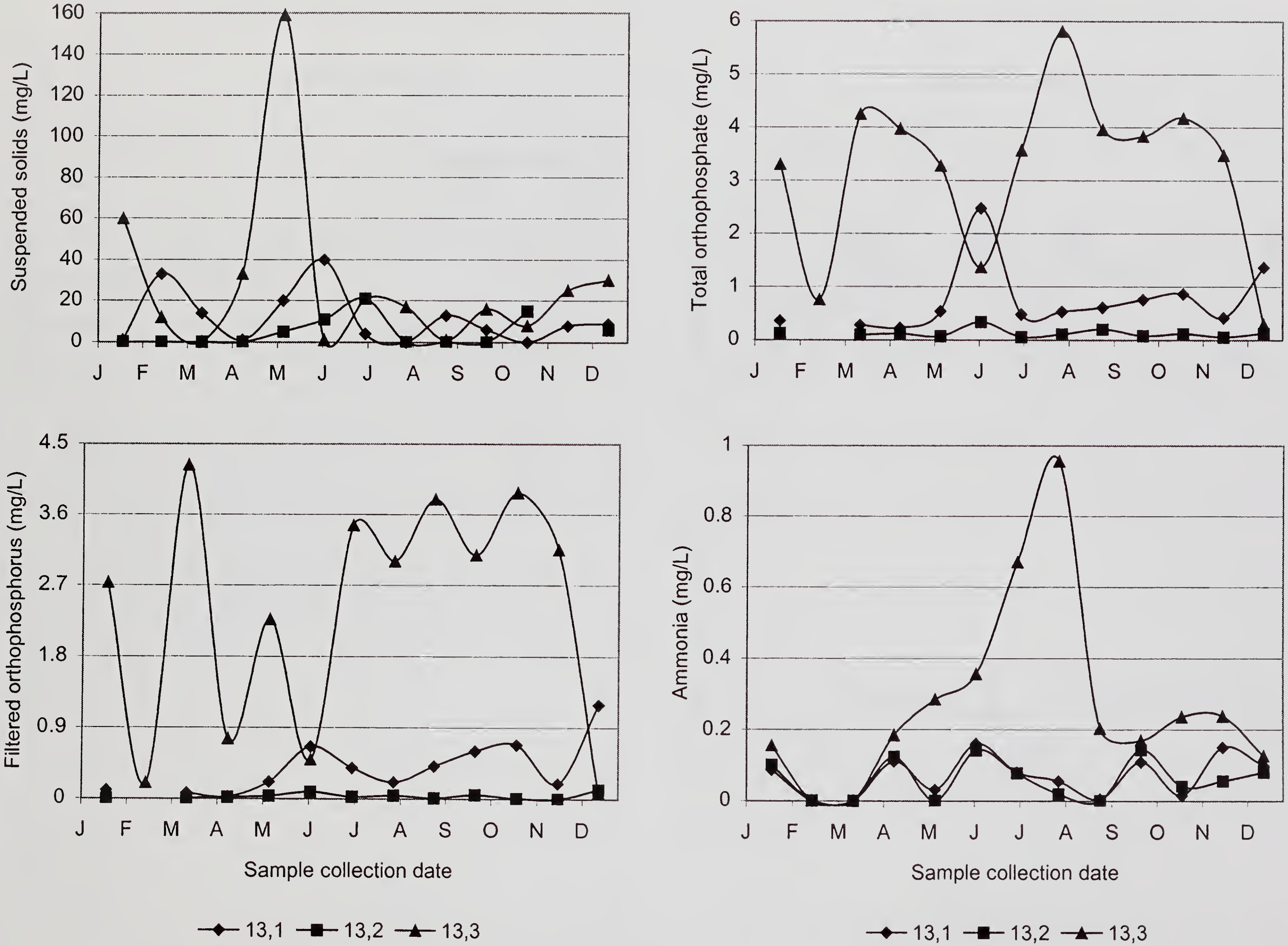


Fig. 13-5. 2000 nitrate, total kjeldahl nitrogen, and chlorophyll *a* concentrations for Burney Branch Creek.

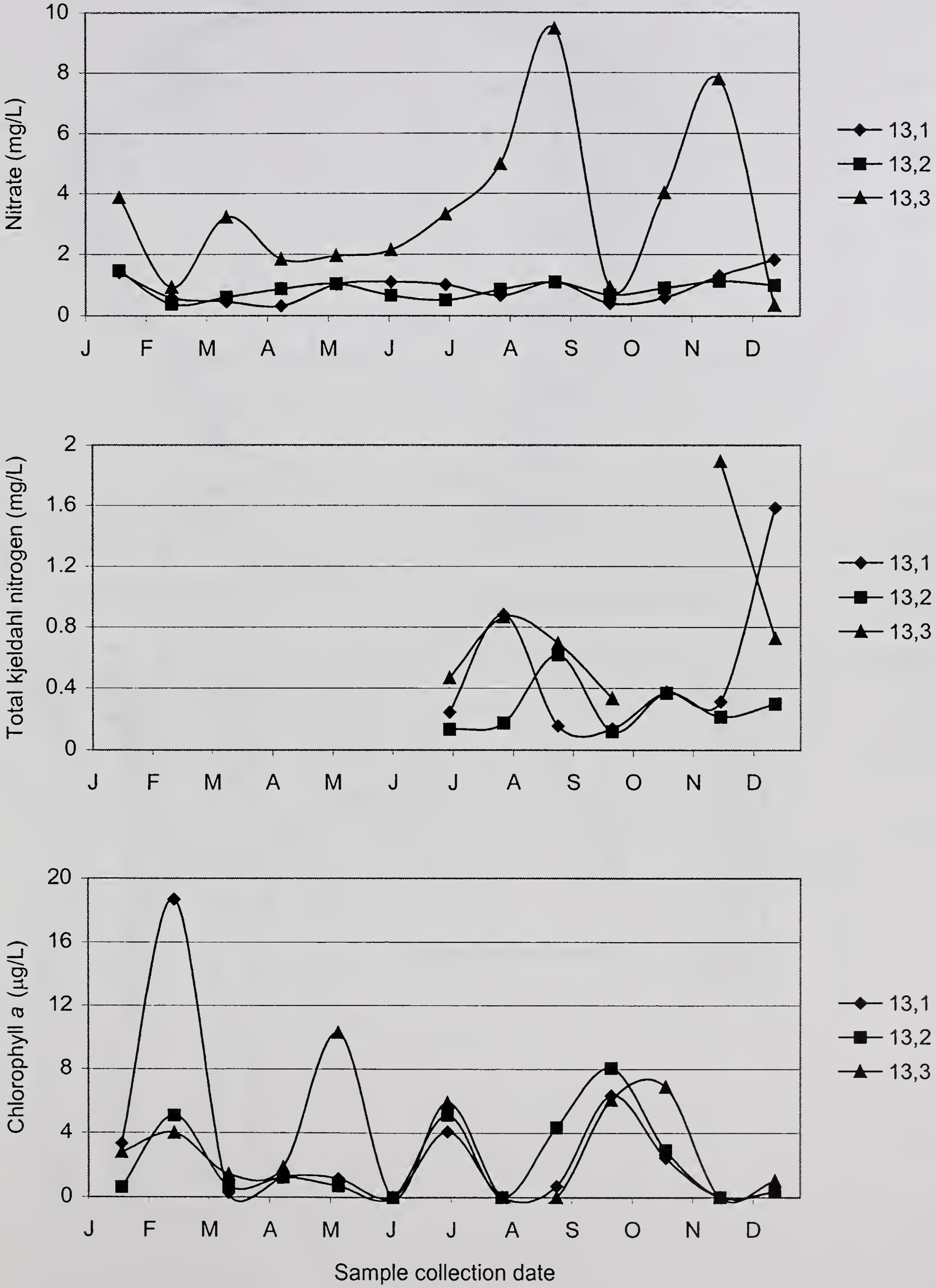


Fig. 13-6. 2000 fecal coliform and enterococci measurements for Burney Branch Creek.

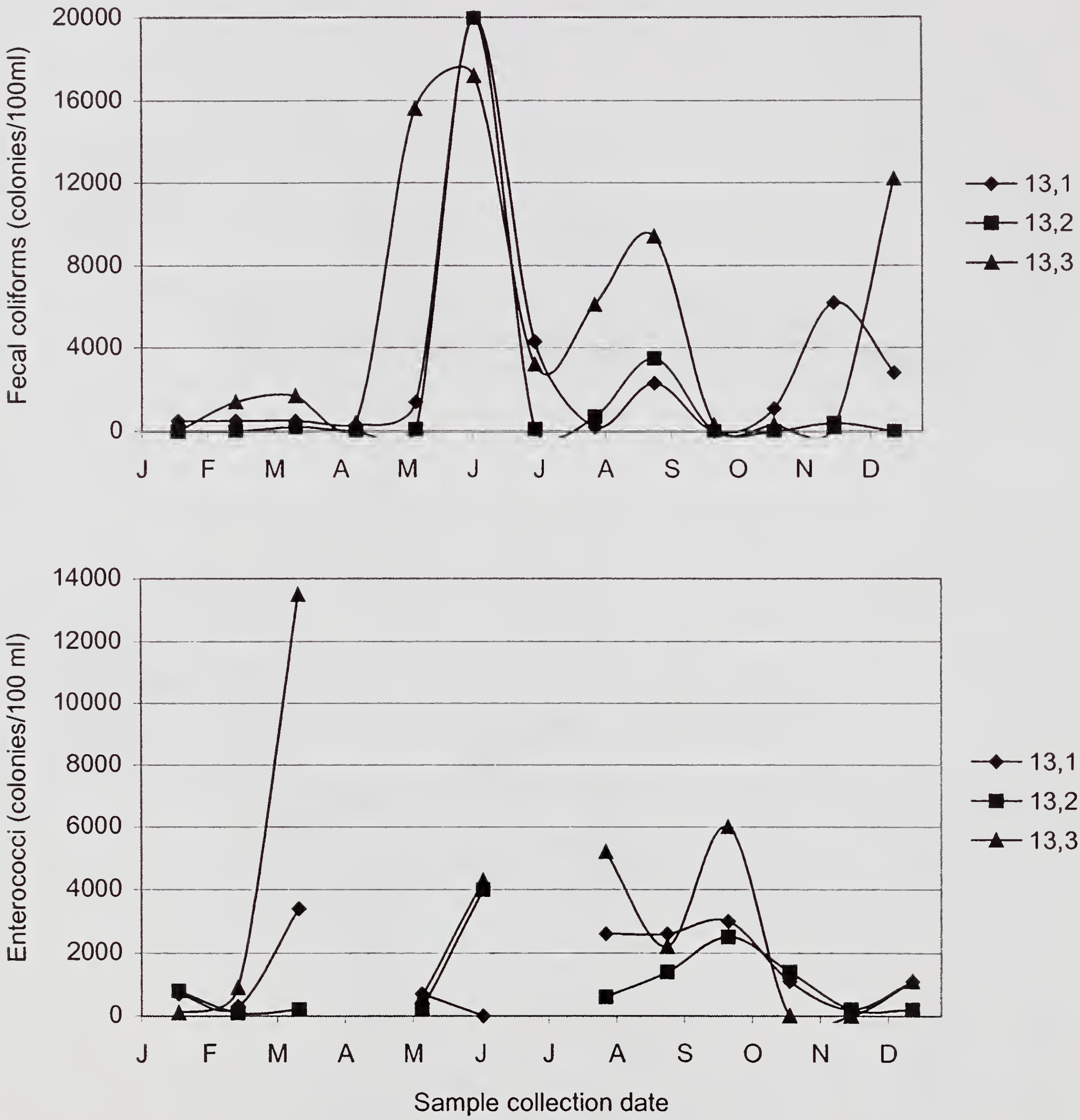


Fig. 17-1. 2000 depth to water, water depth, temperature, and dissolved oxygen measurements for Yalobusha River.

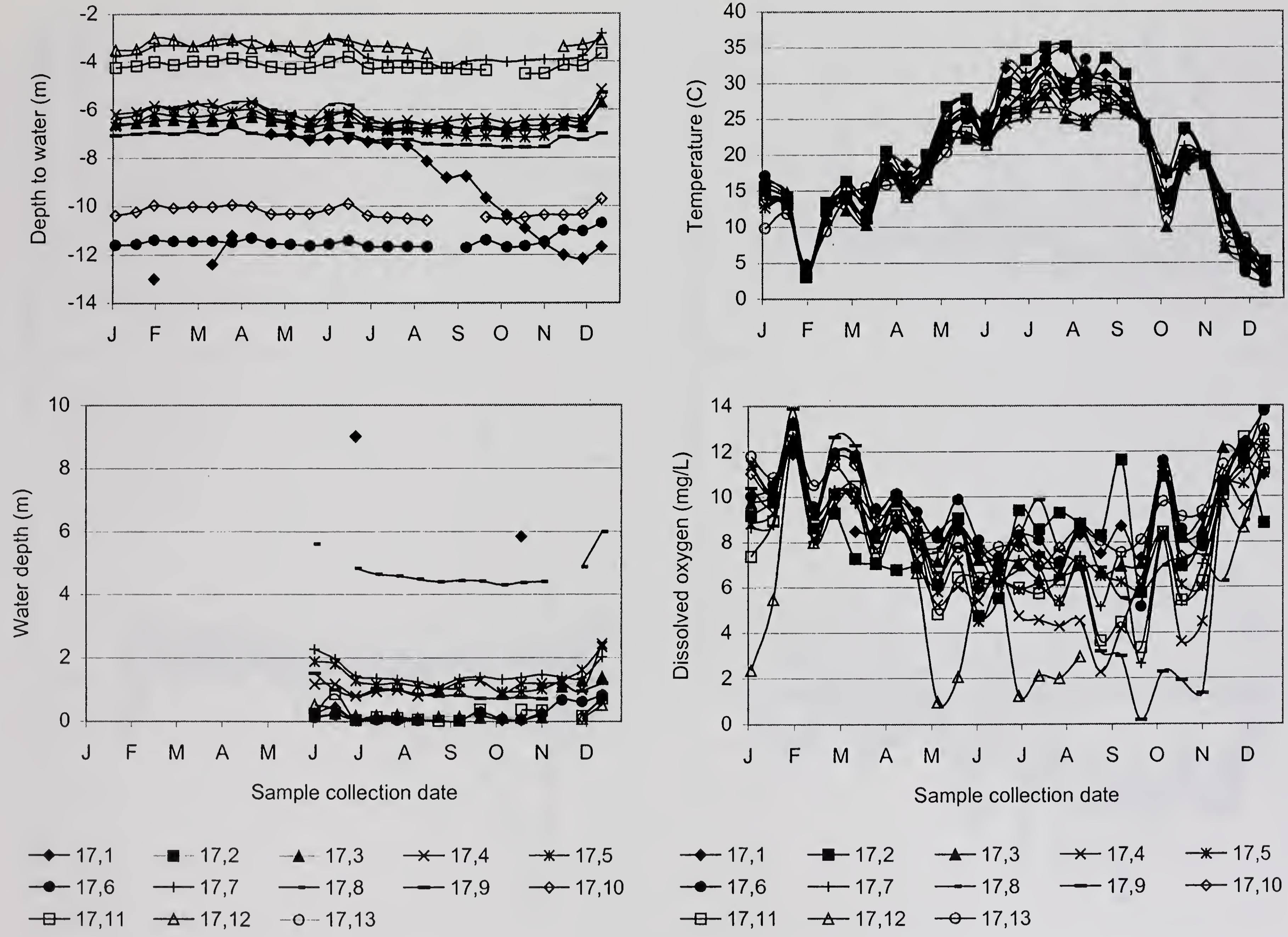


Fig. 17-2. 2000 conductivity, salinity, pH, and hardness measurements for the Yalobusha River.

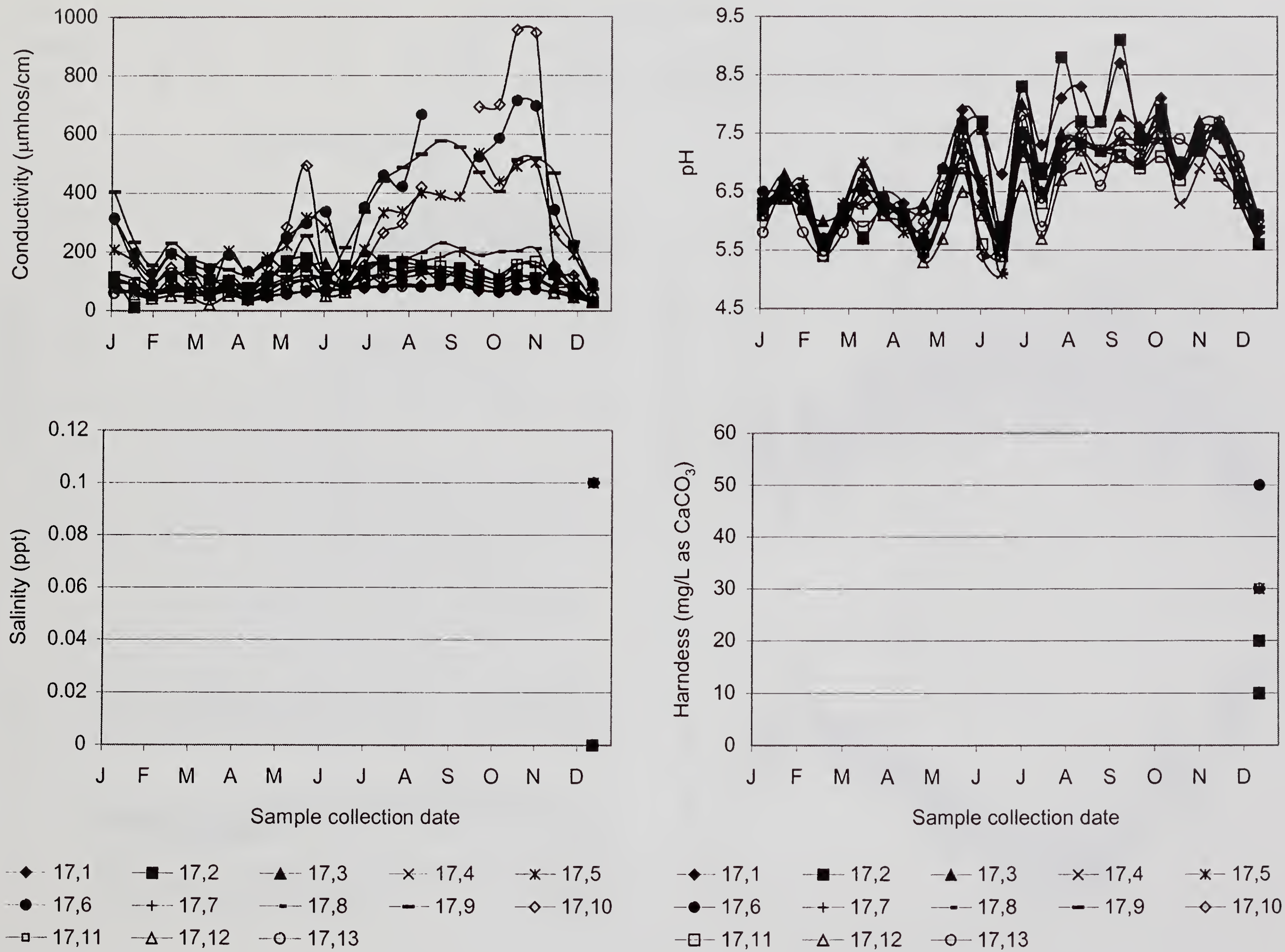


Fig. 17-3. 2000 alkalinity, turbidity, and total and dissolved solids measurements for Yalobusha River.

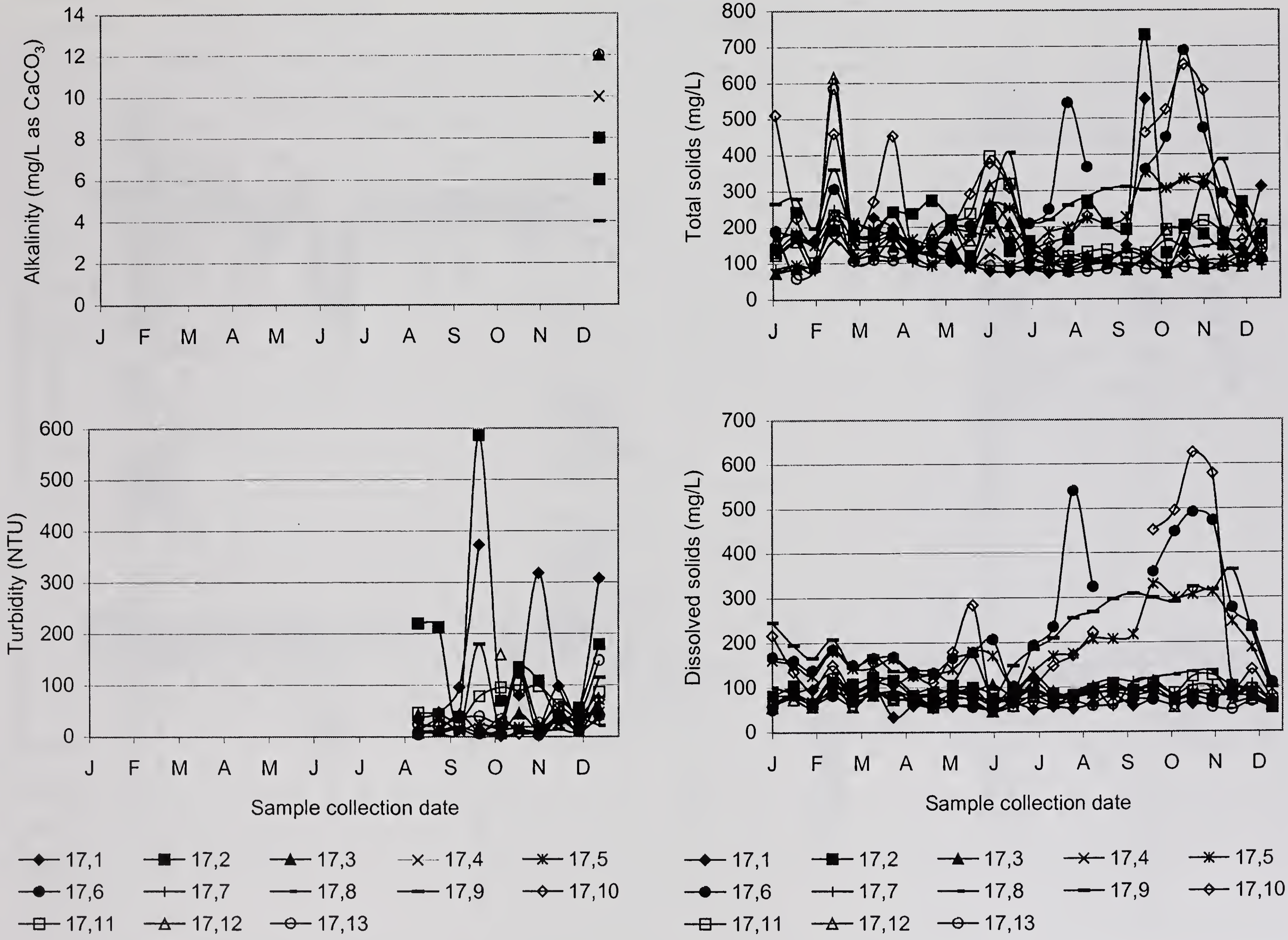


Fig. 17-4. 2000 suspended solids, filtered orthophosphate, total orthophosphate, and ammonia concentrations for Yalobusha River.

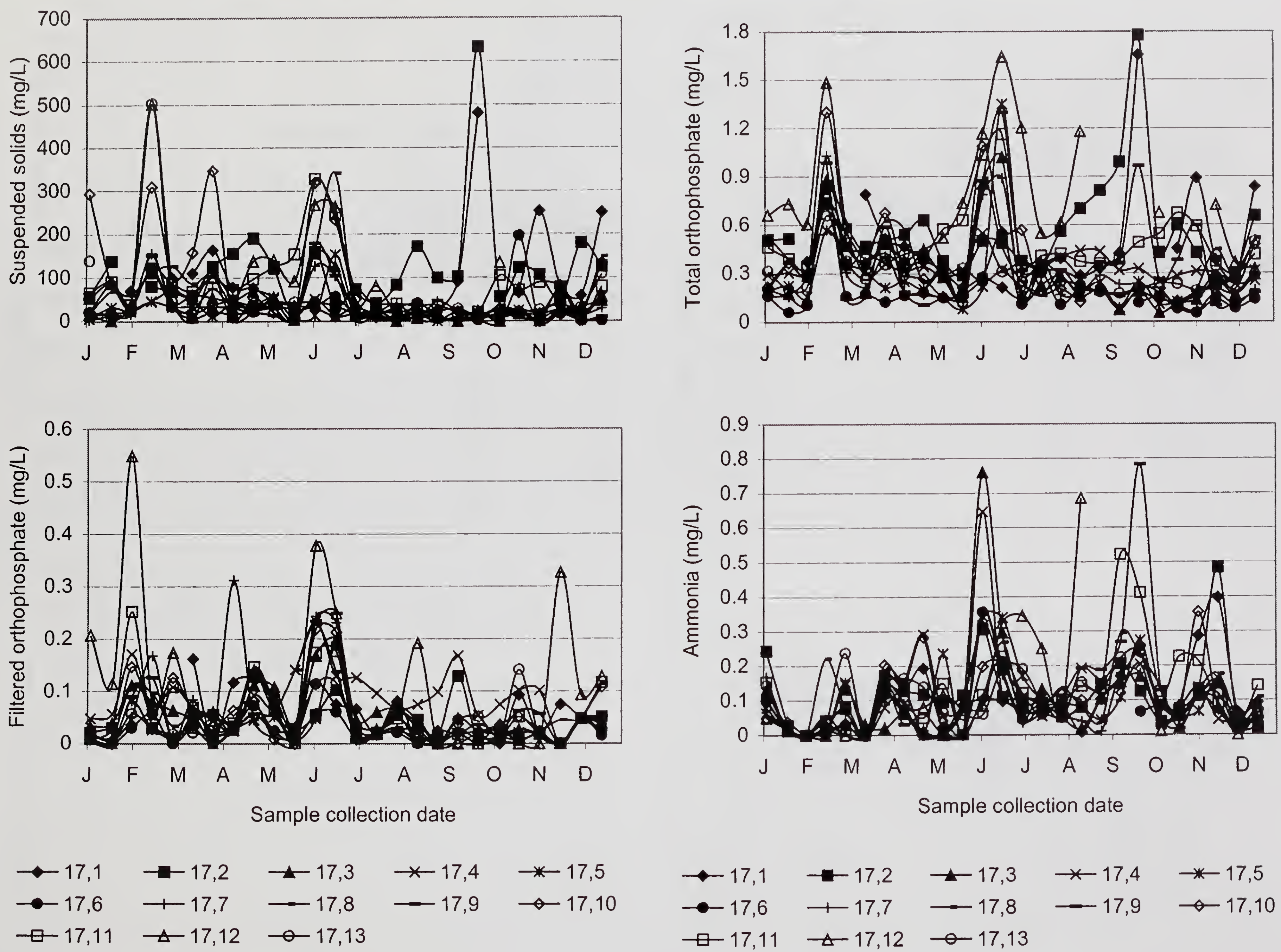
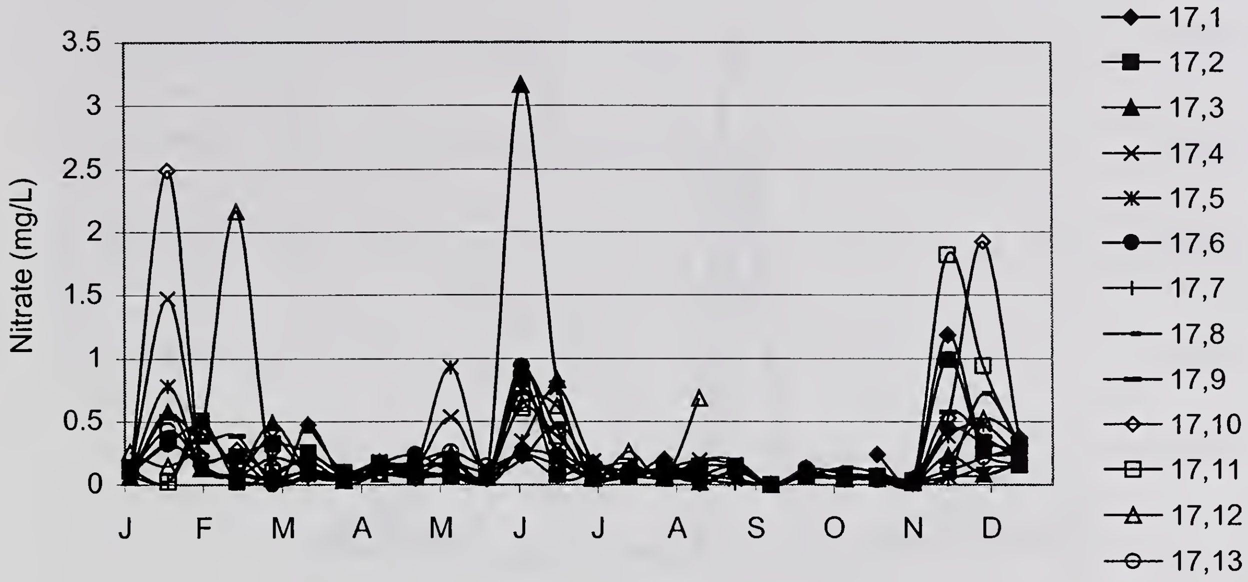
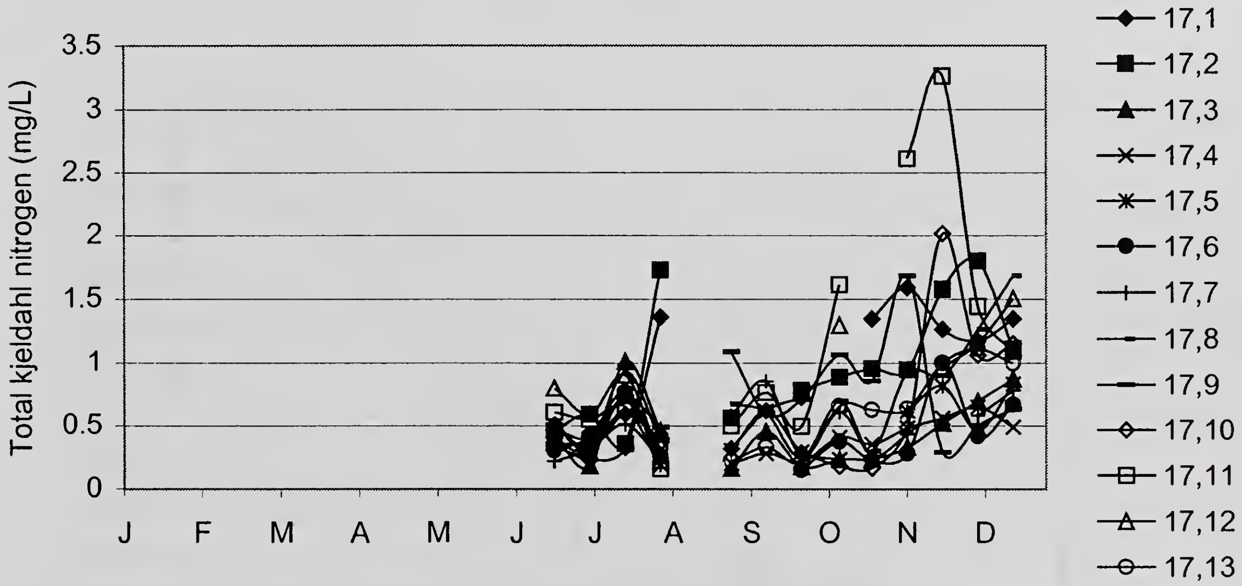


Fig. 17-5. 2000 nitrate, total kjeldahl nitrogen, and chlorophyll *a* concentrations for Yalobusha River.





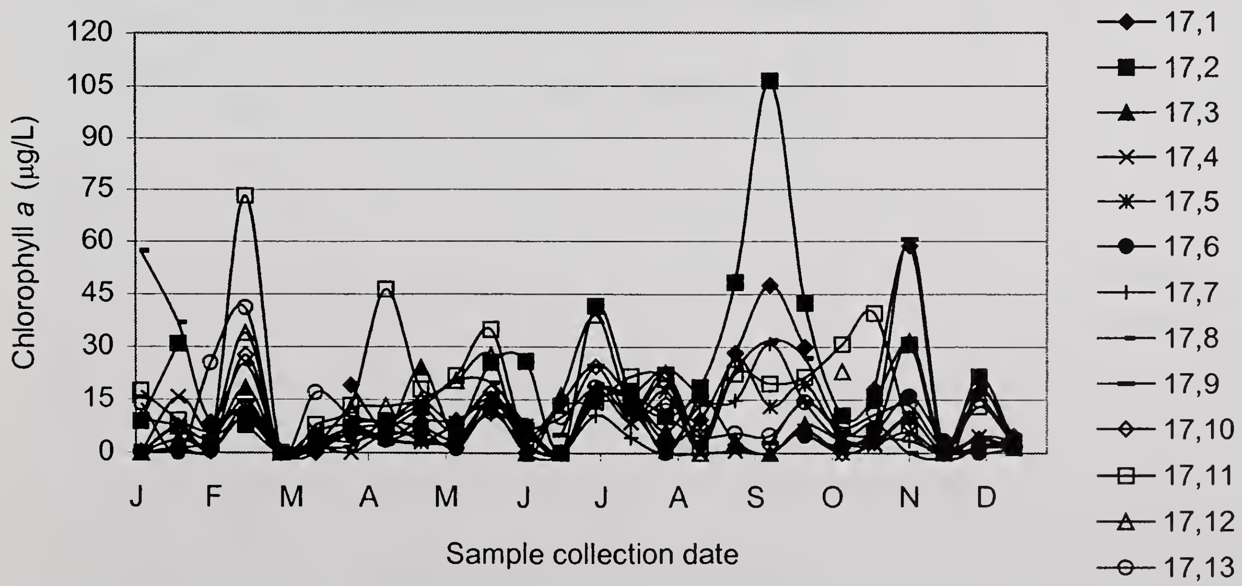


Fig. 17-6. 2000 fecal coliform and enterococci measurements for Yalobusha River.

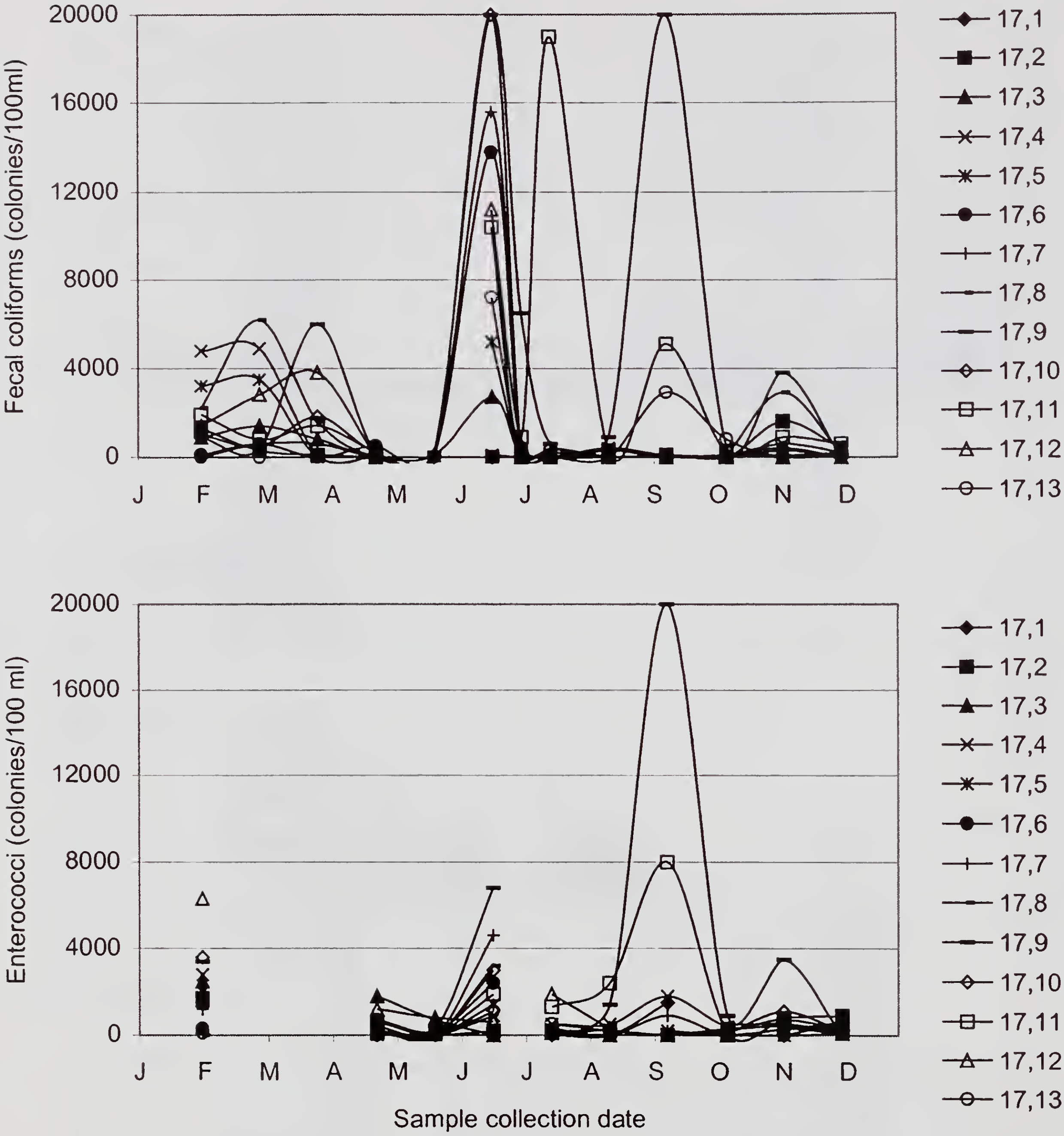
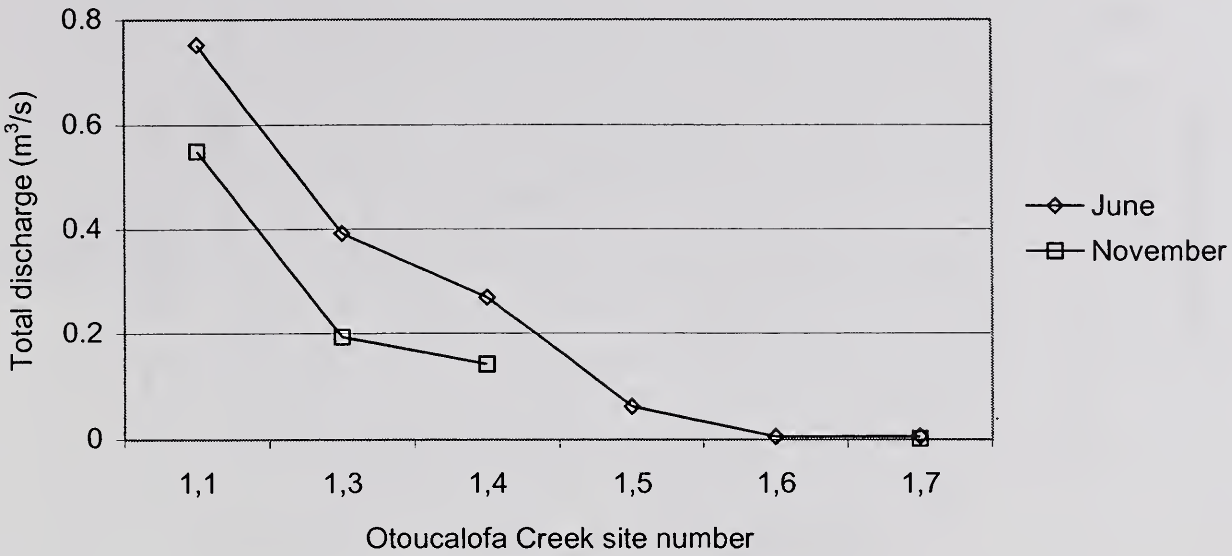
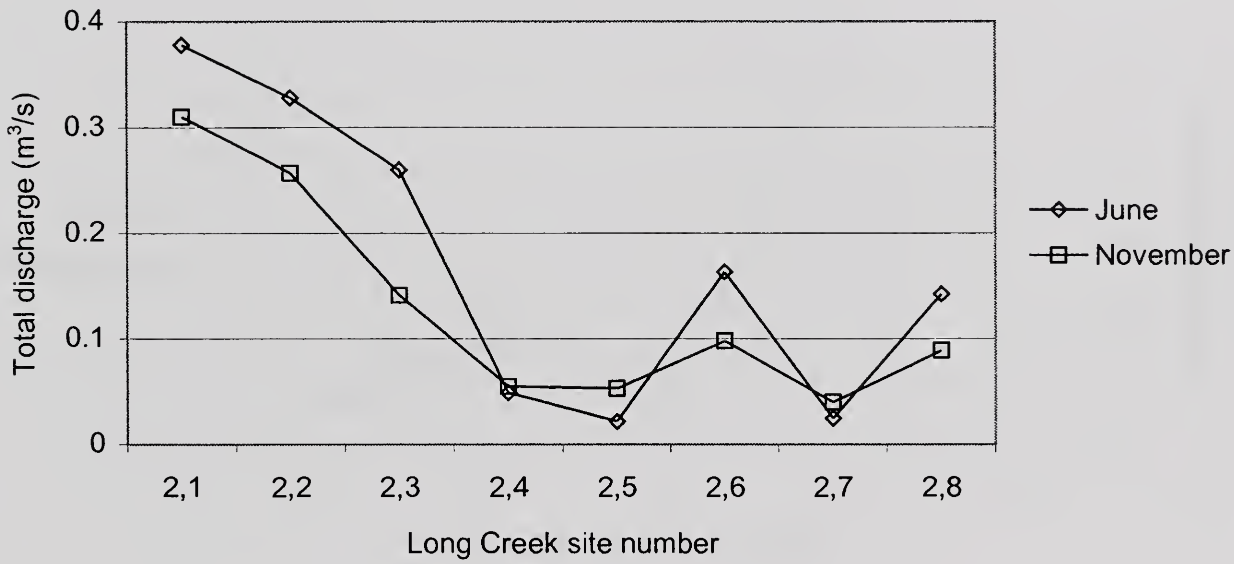


Fig. 18-1. June and November 2000 total discharge for Otoucalofa, Long and Batupan Bogue Creeks.





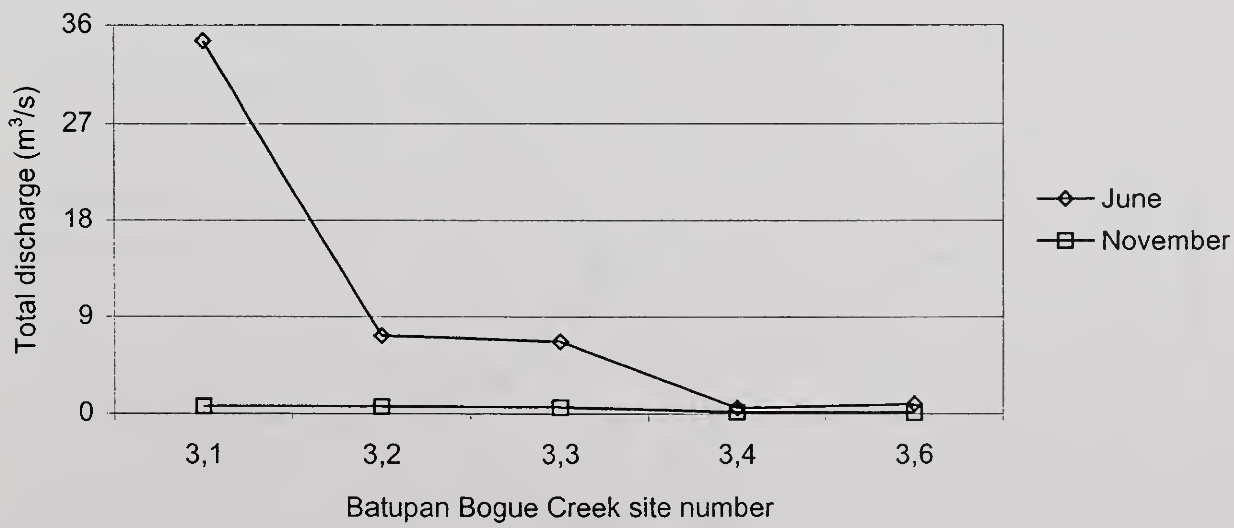


Fig. 18-2. June and November 2000 total discharge for Hotophia, Hickahala, and Black Creeks.

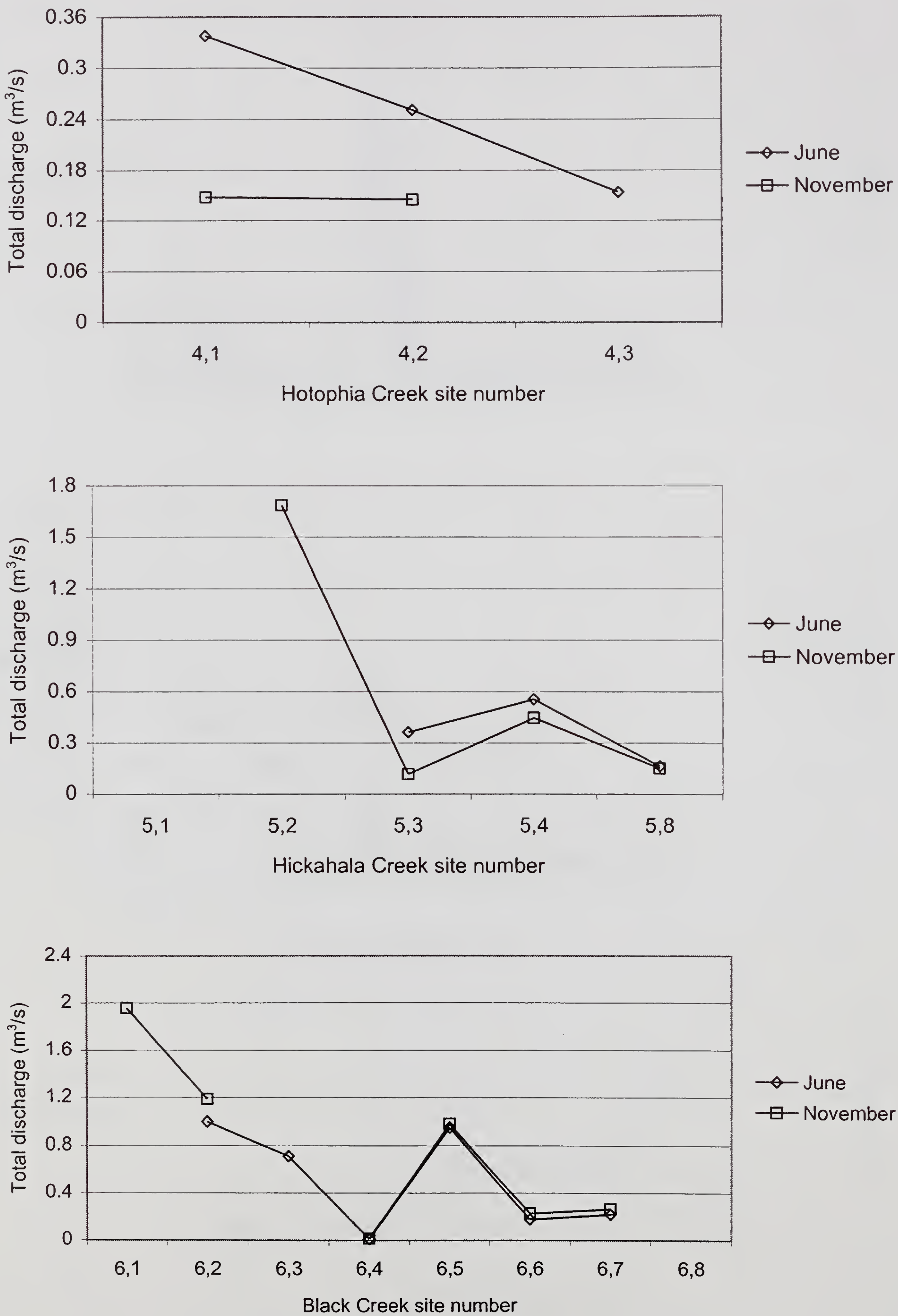
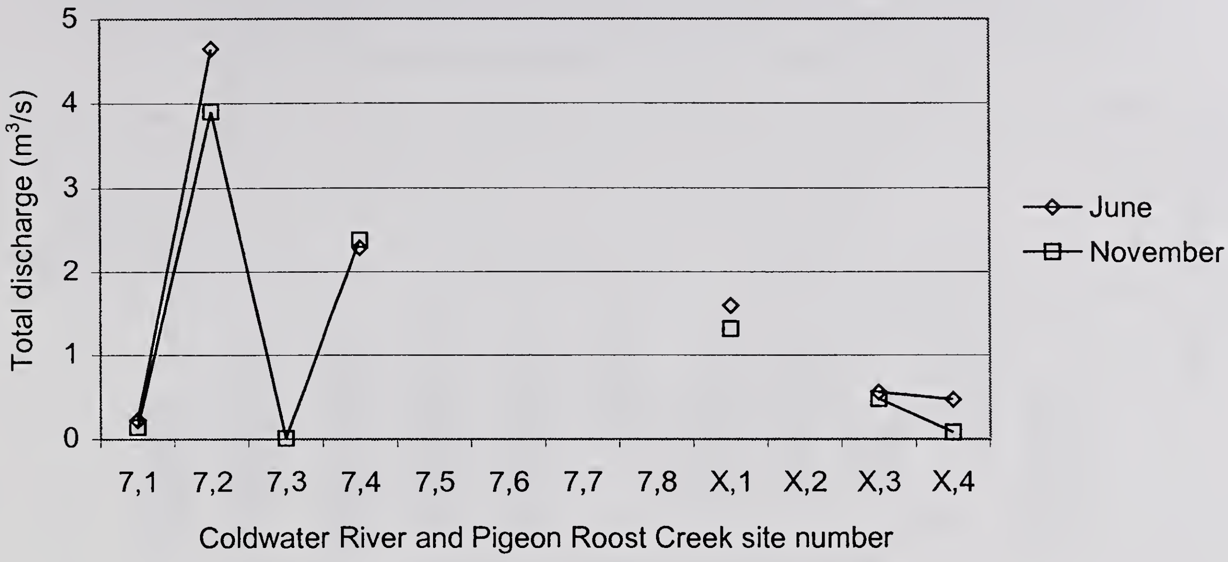
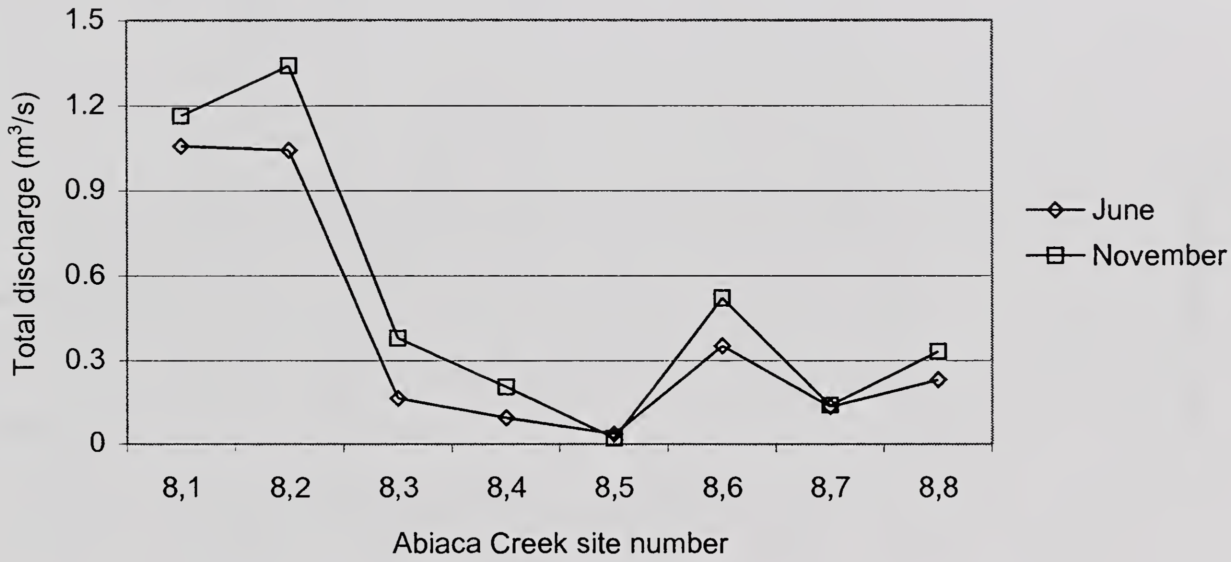


Fig. 18-3. June and November 2000 total discharge for Coldwater River, Pigeon Roost, Abiaca, and Toby Tubby Creeks.





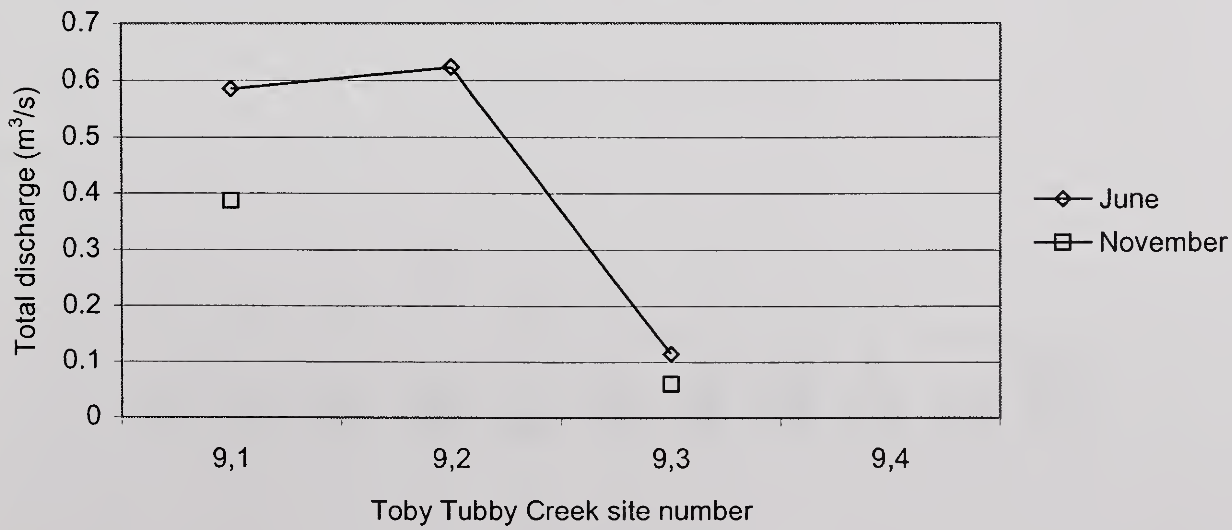
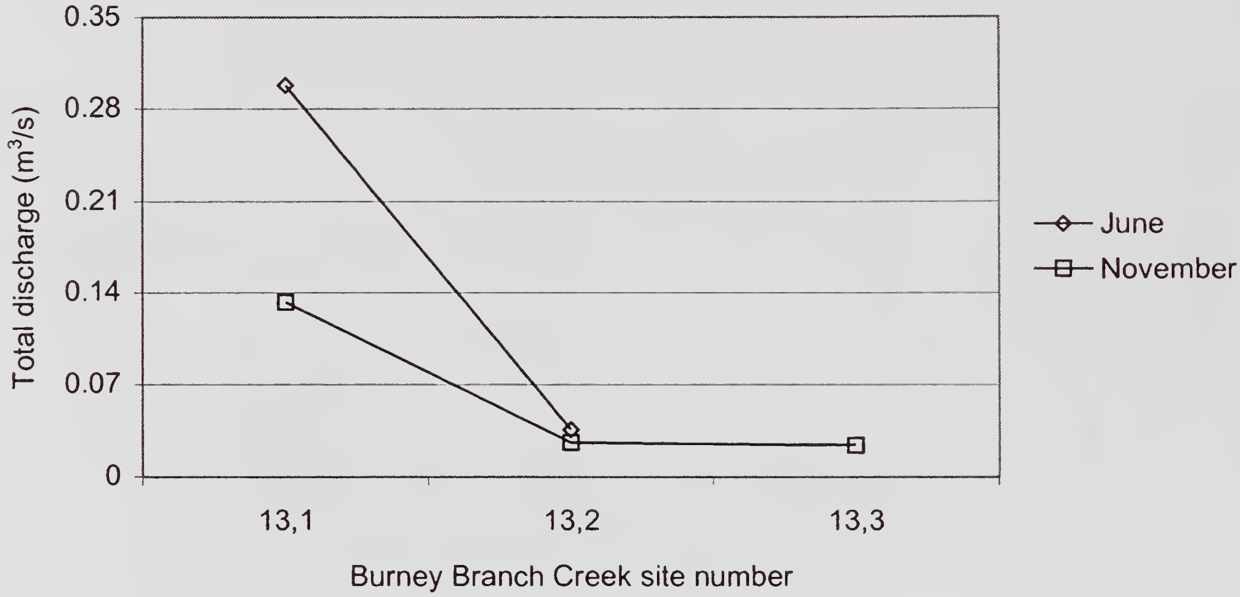


Fig. 18-4. June and November 2000 total discharge for Burney Branch Creek and Yalobusha River.



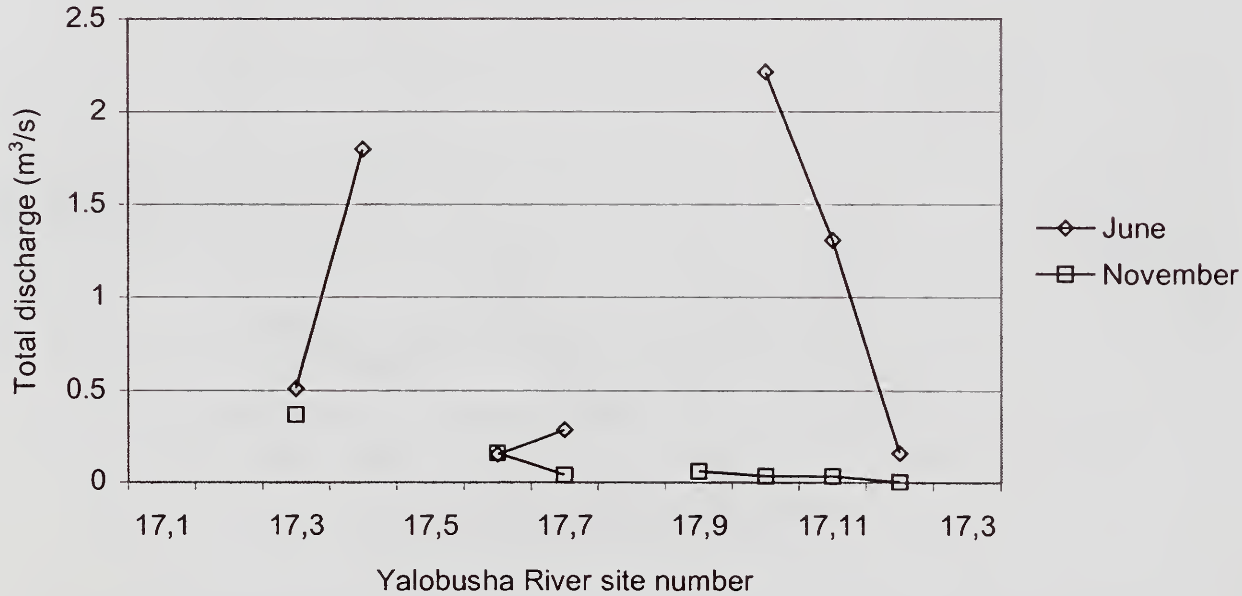


Fig. 19-1. Box plot of 2000 pH values and suspended solids concentrations among DEC watersheds (Box = 25th-75th percentiles; whiskers = 10th-90th percentiles; points = 5th-95th percentiles; solid line = median value).

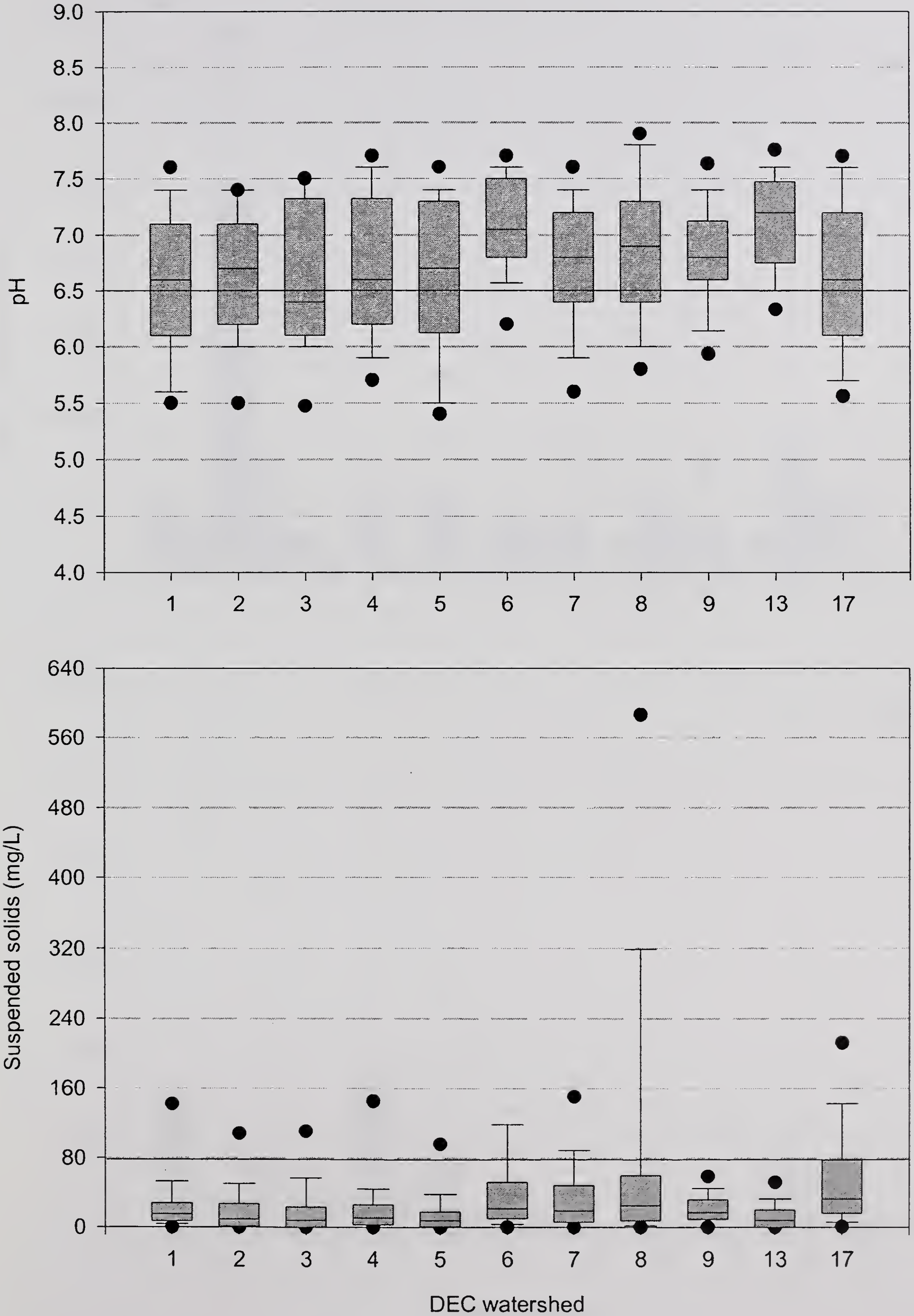
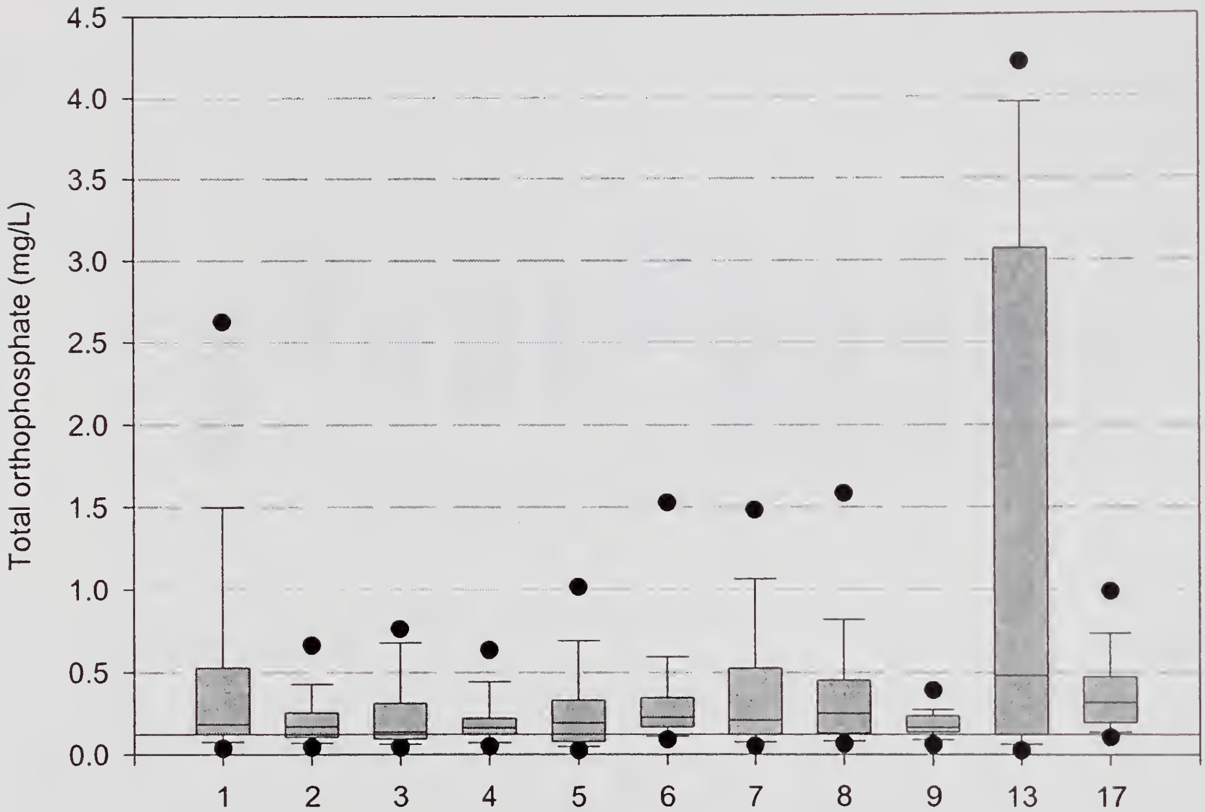


Fig. 19-2. Box plot of 2000 total orthophosphate and chlorophyll *a* concentrations among DEC watersheds (Box = 25th-75th percentiles; whiskers = 10th-90th percentiles; points = 5th-95th percentiles; solid line = median value).



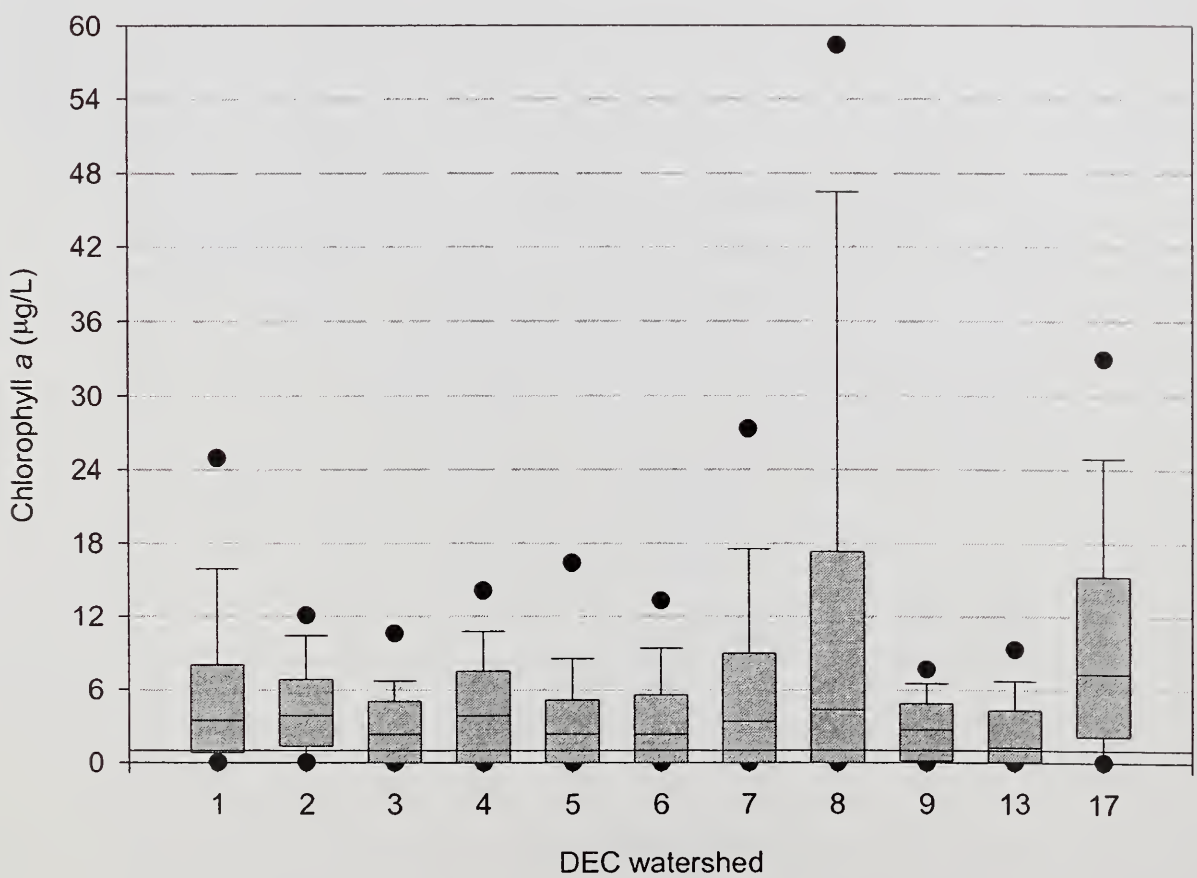


Fig. 19-3. Box plot of fecal coliforms (A) from May to October 2000 and (B) from January-April and November-December 2000 among DEC watersheds (Box = 25th-75th percentiles; whiskers = 10th-90th percentiles; points = 5th-95th percentiles; solid line = median value).